

railgun designs

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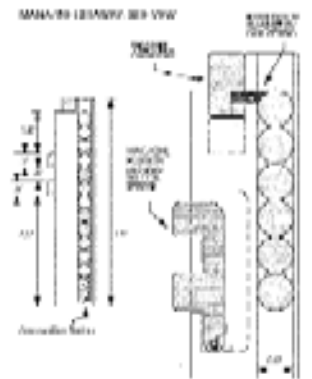
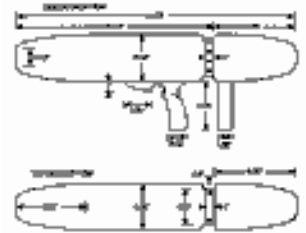
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Overall and cutaway views of my prototype railgun, including working details on case design, layout, and coil positioning.



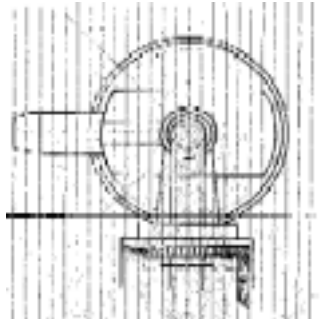
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● Project Overview

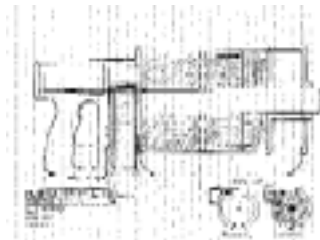
Although I'd read about railguns in science fiction in the early 1980's, I didn't seriously consider it as a weapon of importance or of imminent development potential until around 1992. The idea of a railgun had been stuck in my head after reading a science fiction book where one had been used to launch rocks off the moon's surface into orbit.

In 1994 I began developing my railgun designs, which required a fair amount of research, although my experience was that between scientific and engineering encyclopedias I had little difficulty finding the physics requirements for the physics calculations.



I developed the railgun between early 1994 and early 1996--my research included several formulas and calculations for a number of different potential designs, as well as actually building a few prototype designs, testing of those designs, and the creation of cases to further aid my development and proof-of-theory requirements.

The development of the railgun required a lot of time--I invested well over 2000 hours in the project, although if I'd limited myself to fewer design options I could have reduced that time considerably.



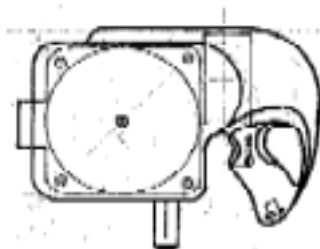
My research into the railgun also led me to the development of several high-energy related weapons, including the portable EMP (electromagnetic pulse) device, which somewhat resembles the railgun, although it doesn't fire a projectile.

After limited success in the testing of my devices, I had proved the theory to myself, and shelved the project to pursue other ambitions.

● Project Goals

The goals of my railgun project were to develop an electromagnetic projectile weapon with the following features:

- High Projectile Velocity
- Rapid Rate of Fire
- Caseless Ammunition
- Few Moving Parts
- Weapon Portability
- Reliable Electronics
- Commercially Available Components
- Light Weight
- Ease of Maintainability



Essentially, I was trying to design a device that a soldier could carry into combat, and use without worries about reliability as a high rate of fire, high-velocity combat device.

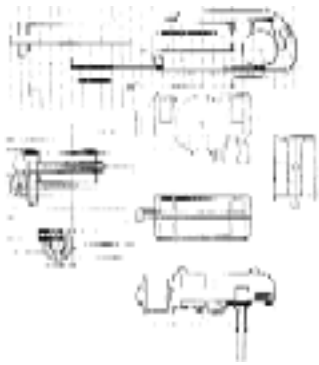
Among the many advantages of the railgun are the reduction in the amount of space required for ammunition--the caseless spherical nature of the ammunition allows greater carrying capacity for the individual soldier.

Additionally, the railgun promises the possibility of much higher velocities than a conventional rifle does--which improves the damage inflicted on targets. Thus, a regular soldier's firepower can be exponentially increased by a greater speed of projectile--especially when taking into account the fact that the kick of a railgun is much less than that of a conventional rifle.

Furthermore, the railgun had to be constructed of reliable mechanical and electronic components, and the added design constraint of commercial availability came into play for the prototype models. Because of the high power consumption of the railgun, as well as the high voltage and amperage requirements, I explored a wide variety of options for reliable componentry--which eventually led me to several options from the power electronics industry.

Because of the tendency of mechanical components to increase the complexity and inherent breakdown risk in any device, I attempted to design the railgun with a minimum of mechanical parts. My reliance on electronics to do the job of mechanical parts was thereby increased, however, my use of highly reliable electronics offset this increased risk of electronic failure.

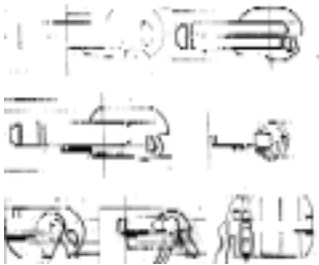
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● Project Success

I achieved success with the railgun project on several different levels, although I never did build the prototypes up to the level of performance that I had hoped to achieve based on my design specifications.

Because of budgetary constraints, I was forced to utilize components that were much less sophisticated than those that I had designed the railgun to use. This led to a lessening of railgun performance to minimal levels--however, the proof of theory for the several designs that I constructed prototypes for was successfully achieved.



I achieved success in both the construction and testing that I undertook, including getting the rail-utilizing design that I developed to actually fire a projectile, as well as getting the solenoid-based system (Gauss Rifle) to perform as predicted.

There were several necessary subsystems incorporated into the railgun that required completion in order to make the prototypes function successfully.

These main subsystems included:

● Rail Accelerator System

The rail accelerator required building an accurate, durable rail system for the projectile to travel down, which also had the requirement of passing current through the projectile in very large amounts.

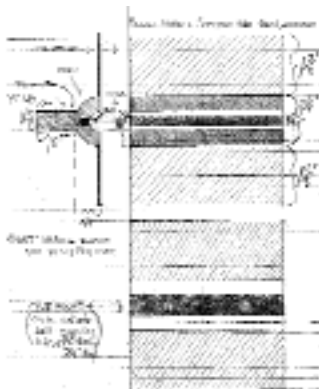
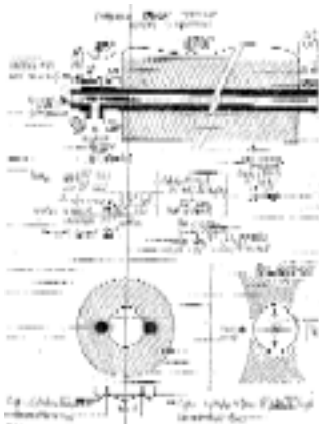
● Coil Propulsor System

The coil propulsor system required constructing a series of coils within very close design specifications. The coil had to withstand high voltages without insulation breakdown, withstand high temperatures without melting, and provide a high amount of magnetic flux to interact either with the current passing through the projectile or the projectile itself.

● Ammunition Loading Mechanism

The ammunition loading mechanism had to fulfill the requirement of loading the ammunition at a high-rate of speed while still using few moving parts and being highly reliable. Additionally, the loading mechanism had to be able to withstand that high amount of magnetic flux coming off the coil.

● Coil Power Supply



The coil power supply had to be able to provide large amounts of power to the coil on demand, while being able to withstand the high temperatures that the current generated. Additionally, the fault tolerance for the components had to be high, and a means of blocking power spikes in the coil system had to be devised.

- **Capacitor Charging System**

The capacitor charging system was required to provide a fast rate of recharge to the main power capacitors from the power supply while maintaining the correct high-voltage, and eliminating the possibility of spikes and other anomolous firing effects.

- **Fire Initiator System**

The actual firing initiator system for the railgun either has to pass the main brunt of the current directly through itself, or else trigger a larger switch that carries this high voltage/amperage load. In either case, the requirements for this type of load were not commonly found in standard compact components, and I resorted to a combination of integrating my own system in with off the shelf parts.

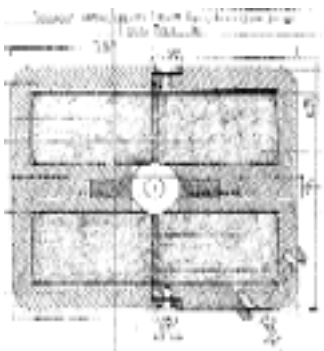
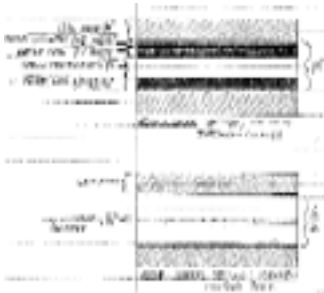
- **Global Recharging System**

The Global recharging system was required to recharge the onboard supply from a main power source when the onboard power was exhausted. This involved finding a way to convert the wall-outlet power source to rapidly recharge to railgun without compromising the batteries by charging too rapidly. Additionally, the recharging system had to also be proofed against spikes, as well as current leakage that might accidentally trigger a self-initiated firing occurrence.

- **Coil Timing System**

The coil timing system involved designing, testing, and tuning several different methods of creating a high-voltage, high amperage electronic pulse through the coil system from the capacitors with a high rate of voltage rise and drop. This also required the timing system to have the ability to provide this HV/HA pulse within a specified time-width, as triggered by the firing system.

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In general, Magnetic Weapons refers to weapons that uses high-voltage/high amperage electronic pulses and/or waveforms to propel a projectile, cause electronic jamming and interference, or serve another specialized military purpose.

● What is a Railgun?

More specifically, when talking about a railgun in the proper sense of the term, the projectile is propelled using Lorentz Force along a rail system that either is the barrel of the weapon or resides inside the barrel of the weapon. A railgun usually has magnetic coils mounted on either side of the rail system at right angles to the barrel, so as to generate Lorentz Force.

Another variation on the railgun concept uses a sling--or push plate--located directly behind the projectile to catapult the projectile out of the barrel at high speeds. This variation on the railgun typically involves the push-plate riding on the rail system, and has the drawbacks of increased complexity, increased accelerated mass (slower overall acceleration--the push plate is heavy), and increased overall friction. Additionally, the push-plate greatly increases the kick of the railgun because it has to stop at the end of the barrel--and there must be a method of retracting it after firing as well.

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I use the term Gauss Rifle to represent an electromagnetic pulsed accelerator for projectiles, although the term Gauss Rifle is sometimes alternatively used by other people to indicate a variety of unrelated electromagnetic weapons.

Instead of using a rail-system and coils at right angles to the projectile, the Gauss Rifle actually uses direct electromagnetic pull on a ferrous projectile. This can be done with either one large timed electronic pulse, or through a series arrangement of small pulses located down the length of the barrel.

A Gauss Rifle has the distinct advantage of not requiring the track system that the railgun needs, because the magnetism in the projectile is an inherent part of the projectile's composition, and not imparted on the projectile by the weapon.

A Gauss Rifle does require more precise pulse timing than a railgun does, because the projectile must pass through the coil while accelerating. If the coil is still activated for any length of time after the projectile has passed through it, then a negative acceleration on the projectile will occur.

● Other Railgun Research

While railguns are popular in a lot of science fiction literature, in reality research on Railguns and Gauss Rifles has been rather stagnant. This lack of research is mostly because of the high costs associated with development, as well as the historical view of the railgun as a non-mobile weapon. Also, the electronics required for the railgun make it prohibitively expensive to make in limited quantities as compared to conventional rifles.

The United States Army developed a railgun mounted in the barrel of a highly-modified tank that used superconducting coils to propel the projectile.

The US Department of Defense was working on the concept of using orbital stationed railguns to shoot down missiles over the US.

Information Unlimited and Amazing Concepts Inc. developed prototype Gauss Rifle that used Anti-ferromagnetism to propel an aluminum ring away from a high-powered electromagnet. Unfortunately, anti-ferromagnetism is so much less powerful than ferromagnetism is that the Information Unlimited model is unlikely to ever be fully developed.

Magnetic Impact Weapons Overview

Page #1 of 2, by Tim Ventura

1. Overview

The realm of possible weapons applications for magnetic impact weaponry is virtually limitless. Featured in a multitude of various media over the last few years, "Railguns" and "Gauss Rifles" have seen imaginative popularity everywhere from movies and cinema to role-playing games--and have been pictured in configurations ranging from large, bulky, spaceship-carried cannons, to slim, tapered rifles.

To avoid confusion, the term "magnetic impact weapon" is used from here on to describe a device using magnetic forces to propel a projectile in a controlled manner--the terms Railgun and Gauss Rifle merely describe specialized variations of magnetic accelerator systems, and will be described in detail later. The intent of a magnetic impact weapon is identical to that of a conventional firearm--that is, to deliver a projectile to a predetermined target for the purpose of inflicting kinetic damage upon that target. Aside from that design intent, MIW's and firearms bear little resemblance.

The desire to incorporate a magnetic propulsion system into a projectile weapon is a fairly old one. In fact, the world's first gauss rifle was invented shortly after 1900, with the inventor's hope lying in interesting the US Navy in utilizing it for submarine torpedo launchings. This particular use was because the device weighed several tons, and had very low velocities compared to any conventional firearm--however, the device was documented to propel a six-inch diameter projectile through 2 inches of plate steel from a distance of 20--demonstrating a startling potential. Other similar weapons have been tested and abandoned for

various reasons. A well-known aircraft manufacturer, for instance, is reported to have experimented with incorporating a railgun into a fighter-jet. The company apparently believed that overall vehicle weight would be reduced by a lack of projectile propellant and shell casings--and the jet's turbines provided more than enough electricity for the necessary electromagnets. Apparently those electromagnets were heavier than expected, and the project was subsequently abandoned.

Even in the scant 15 years that has elapsed since the end of the 1970's, electronics technology has progressed at a remarkable rate. Thus, the concept of producing a workable railgun or gauss rifle is now a reality. The magnetic impact weapon is now competitive the firearm in terms of size, weight, velocity, cost, and durability.

2. Competition

Why would anyone waste time and money in creating a magnetic weapon to compete with the already existing firearm that serves the application need perfectly well? There are in fact three answers to this question. First, for a company that can develop the weapon to a point of marketability, there is a monetary reward comprising a part of the extensive weapon's industry income. Second is the future potential of the magnetic weapon--it can surpass the standard firearm in every competitive category within the near future, provided that it is sufficiently developed. Third, there are already present features of the magnetic weapon that cannot be obtained by conventional firearms due to various legal and design restrictions

[Continued on page 2...](#)

Magnetic Impact Weapons Overview

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mag. weapons, continued...

Magnetic weapons are silent, fully-automatic, use larger caliber projectiles, are electronically controlled, and much safer than firearms. Technically, since they are not firearms, the restrictions on silencing and repetition of firing may not apply. Since magnetic weapons use electricity instead of chemicals as a propellant, an array of simple controls can allow the operator adjust previously unchangeable features, such as the projectile's velocity, or the exact number of projectiles to be fired per second. Also, since the weapon cannot discharge without the power being activated, the device cannot accidentally fire if properly handled--even if dropped or subjected to heat. A code-key could quite easily be added to prevent operation without the proper user's code--to prevent theft or a child fatality. These are all features which are not incorporated into conventional firearms--many of these features indeed cannot be.

3. Applications

Magnetic weapons have many present and future applications, both general and specialized, that will ensure their presence in the future. The competitive features found in magnetic weapons design prove to be optimum for the modern role of weapons in capacities ranging from home-defense to hunting/sporting applications, to the demands of military duty.

Americans in the 1990's and beyond are presently in crisis over home defense. It is obvious that a weapon is one of the best of all measures for stopping a hostile, frequently armed burglars and intruders. However, the crisis appears because of the possibility of the intruder using the weapon against the owner--or because of the fears of a parent worried about the increasing number of children who accidentally harm themselves with firearms. Magnetic projectile weapons offer a

A lock of this sort can be integrated into the device in such a manner as to make the device completely inoperative to anyone who doesn't know the code--even if the device is disassembled to circumvent the lock. Since weapons are deliberately stolen by many criminals, this not only prevents the weapon's use on the homeowner, but also on anyone else if the device is stolen. Also, the worried parent may relax with the knowledge that the weapon is completely safe with their child so long as that lock is active.

To the extent that hunting and sporting purposes are concerned, the magnetic weapon offers several advantages over the conventional firearm. First of all, the weapon's silence and lack of "muzzle-flash" will allow the hunter a greater chance to acquire his or her quarry. If the prey is missed, it will not necessarily flee due to these rather intrusive features of firearms. Also, the weapon's safety will come as a great boon to the hunter--as hunters are frequently injured by guns that are dropped and accidentally discharged. And finally, a feature beneficial to hunters and sportsmen alike is the device's reduced recoil. Unlike a conventional rifle, which produces a sharp, sometimes painful recoil, the magnetic weapon will produce recoil similar to that of a shotgun--a dull push. This will aid in increasing accuracy, due to an increase in ability to maintain aim throughout the firing process.

In a military capacity, the device can incorporate many features in addition to the already beneficial silence, lack of muzzle-flash, and increased aim-control. For instance, an electronic readout may readily count the amount of ammunition remaining in the magazine, as well as predict projectile velocity. Also, the control system may easily allow the soldier to control the rate of fire by simply selecting the desired rate of fire on a control panel.

solution to this crisis--a solution that comes in the form of an electronically-coded "lock" that disables the device until the proper activation code is input.

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Do not work with high-voltage and/or high-amperage power systems without training!

Do not work with chemicals, fiberglass material, or any other toxic chemicals without proper training and equipment!

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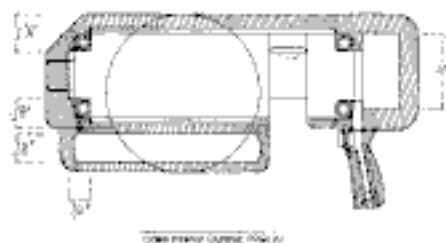
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● Prototype Railgun

I built the prototype for my railgun design in early 1994--it took about a month of construction time to build, and consisted of a magnetic coil placed at a right angle to a two-railed "track" that the projectile traveled down.

I learned a few things about the construction of a railgun based upon my experience building the prototype. To begin with, you should always use a track material that is non-metallic, because at the kind of amperage required for lorentz force to propel the projectile, the unfortunate consequence is that the projectile will instantly weld itself to the track. This was merely a minor engineering setback as I looked for a suitable intermediary lubricating material between the projectile and the track.

● Railgun Coil Position

As you can see from the graphic to your left, the railgun utilizes a side-mounted coil to push against the current running through the projectile from the charged track halves. This railgun design mimics, at least to some degree, what the Army played with in their conversion of the tank in a larger railgun. Unfortunately, what the Army didn't realize is that the power required increases exponentially with projectile size, which means that their design wasted enormous amounts of energy.

● Railgun Cutaway

The cutaway shown of the railgun at left shows a possible configuration that would allow the oversized coils to be placed in a relatively small case design. The weight of this device is another story however--even with state of the art electronics, the weight of the railgun will be around 20 pounds or more, which makes it too heavy for extended carrying.

Notice the drum clip inserted in the bottom of the railgun (shown in side and top views). The drum clip is one of the easier designs to create, as well as holding a large amount of ammunition. Additionally, many of the features that make the standard clip so reliable are based on the cylindrical shape of the ammunition--since the railgun doesn't need cased ammunition, you can use completely spherical ammunition.

● Accelerator Design

The graphic on the left bottom portion of the page details the accelerator part of the railgun. This is the modular portion that handles the functions of accepting the magazine, loading the ammunition, and

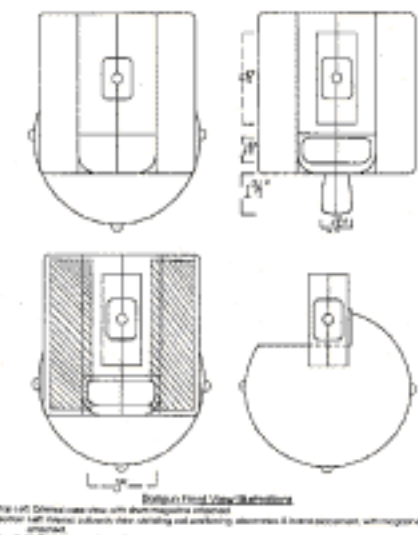
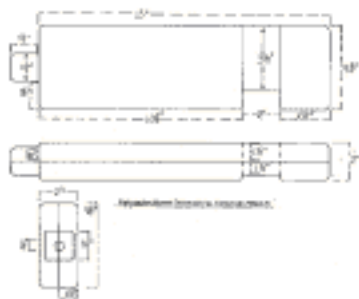


Fig. 1-10 Cutaway view of the railgun showing the internal components. The top view shows the internal components of the railgun. The side view shows the internal components of the railgun. The bottom view shows the internal components of the railgun.



providing the firing sequence apparatus and the barrel. The coils are mounted on either side of this and are not part of it.

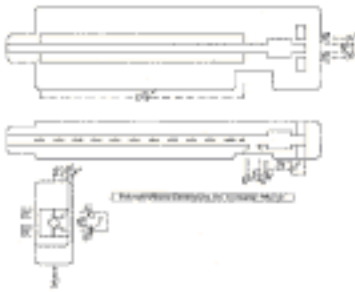
● Railgun Physics

The physics behind a railgun are essentially the same as those that describe the forces that make a common electric motor turn.

Essentially, the railgun uses Lorentz force, which occurs between an electric current and a magnetic field. For instance, when an electric current cuts across a magnetic field, it will experience a torque in a third direction. Therefore, if a current is run through a projectile that is in a magnetic field, the projectile will experience a push in a third direction, which is down the length of the barrel if the current is flowing in the correct direction.

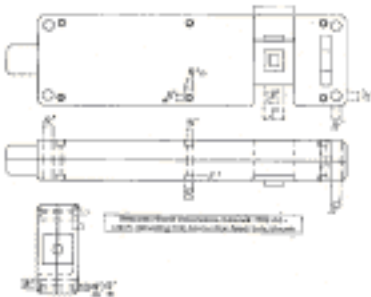
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● Accelerator Graphics



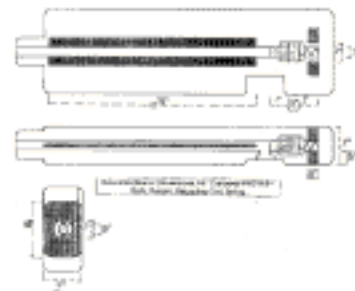
The cutaway on the top left illustrates in greater detail the cutaway view of the accelerator portion of the railgun, and the path that the ammunition follows while loading and firing.

The second graphic from the top illustrates in greater detail the exterior layout of the accelerator, including the side insertion port for the cylindrical magazine.



The third graphic shows in greater detail the reloader and barrel dimensions in another cutaway view of the accelerator. Notice the plunger also shown--it contains an electromagnet inside it for more accurate pre-fire projectile positioning.

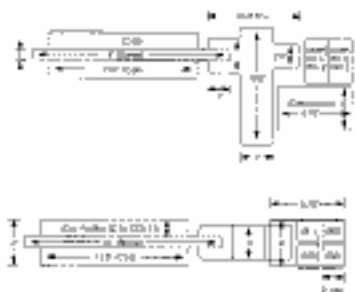
The final graphic shows another view of some of the interior dimensions of the accelerator, and their relationship to some of the other interior components such as the battery pack and electronics compartment.



● Projectile Overview

I opted to utilize chrome-steel bearings test the prototype Railgun and Gauss Rifle with. The reasoning is that chrome-steel bearings are inexpensive, manufactured to very close physical tolerances, and they are ferromagnetic.

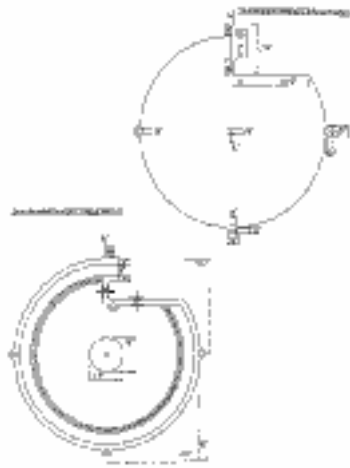
The bearing size that I opted to experiment with was 50 caliber--or one-half an inch in diameter. This provided a substantial size, which allowed more access to creating the barrel of the prototypes.



● Propulsion Stages

I experimented with several different propulsion systems for the Railgun and Gauss Rifle. The primary system was the single stage high-amperage coil configuration, which can either directly attract the projectile (Gauss Rifle) or be positioned at a right angle to a current-carrying projectile (Railgun). In science fiction literature, the multi-stage attraction of the Gauss Rifle is often portrayed as the best method, however, in a testbed platform, this raises the possibility for design error to unacceptable levels, especially when you consider the timing implications for the multiple coils in the barrel. A regular Railgun can also have multiple coils, however, they won't have the direct series effect of the muti-coil system in the Gauss Rifle.

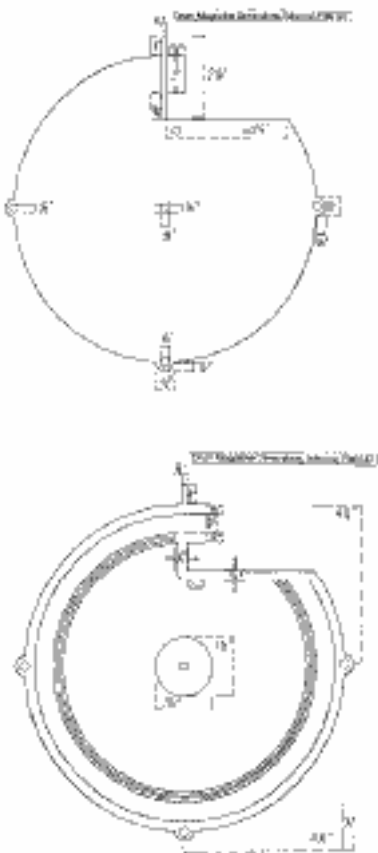
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● Railgun Magazine Design

The magazine for the railgun in this particular case is similar to that used on the Thompson special (a.k.a., the infamous "Tommy Gun"). One of the reasons for that is basically because I wasn't sure how exactly to handle having completely spherical, caseless ammunition.

The Magazine isn't particularly special, however, I had planned to include an insert that would allow me to change the caliber at a moment's notice--this would especially help testing of the railgun with different types and weights of ammunition.

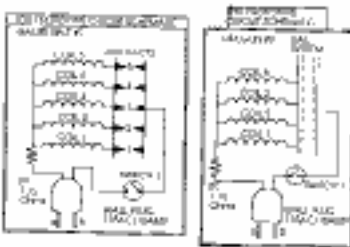


● Prototype Circuit Schematics

This graphic shows a couple of the design ideas that I had for simple test models--I wanted to find a way to build a series of cheap, flexible test models based on a common design. This would allow me to change several parameters without a large investment of time and money.

The test schematic for the gauss rifle shows it as being plugged into the 120volt wall-socket just to illustrate that it requires a power source. Also, as you can see from the graphic, there are multiple contacts inside the barrel, which indicates that this is a multiple stage accelerator.

The test schematic for the railgun shows how the power source is generally hooked into the rail system--and how the rails are used to pass current through the projectile. This is a highly simplified diagram--especially when considering certain elements like the listed "switch". In reality, there are a variety of high-voltage switches available, however, it's likely that a railgun switch will at some point require mechanical component design for tolerances of heat unknown to most stock circuit switches.



● Electronics Components

I employed a variety of electronics components in my Railgun and Gauss Rifle designs, and had the option to incorporate a wide variety more than I actually needed.

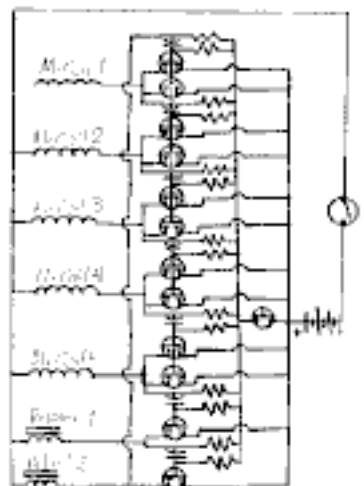
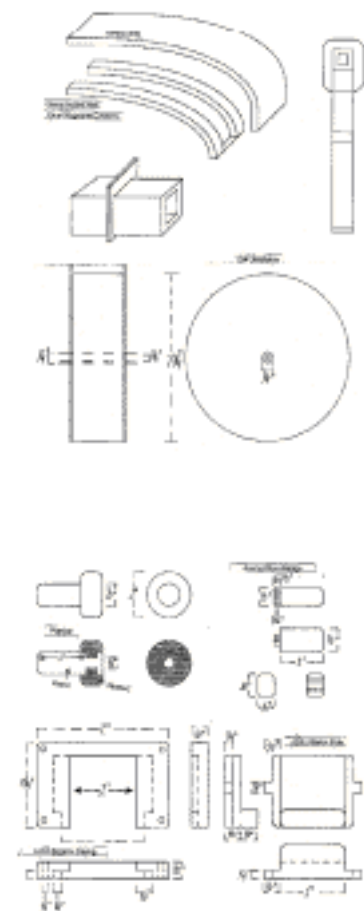
Most of the components used in the Railgun are power electronics elements, including high voltage/high amperage MOSFET power switching transistors, silicon controlled rectifiers, industrial electrolytic capacitors, and power electronics relays.

To reduce weight to manageable proportions for handheld weaponry, I opted to go with MOSFET switching transistors and SCR's whenever possible--they allow switching of a great deal of power when necessary in a small and discrete electronic package.

The option to use high-power relays was also available, however, because of the power requirements, the size of relay that would have been required would have been large and unwieldy.

Another option that I explored was using a spark-initiated point-gap for the main discharge sequence, however, point gaps are likely to undergo degradation and require mechanical maintenance.

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Miscellaneous Parts

There were a variety of loading mechanisms that I had to design, especially with regard to ammunition loading. I found that in comparison to a normal projectile weapon, the firing process was actually less complicated than the loading process. This is primarily because the firing is electronic in nature, and hence is subject to different limitations.

Multi-Stage Circuit Design

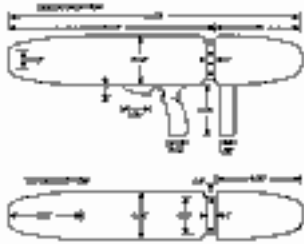
I've included one of my many multi-stage circuit designs so that you could see the scalability of the railgun to include larger projectiles and higher speeds. The primary reason for multiple stages is that the required acceleration for each given stage can be reduced, which greatly eases constraints from magnetic hysteresis in the projectile, as well as allowing the use of lower overall voltage and amperage in the coils.

There are many potential ways to set up timing on the multiple-coil circuit. Each of the succeeding coils must turn on and then off at exactly the correct times to properly accelerate the projectile--I had considered using a mechanical system of brushes to actually limit the coil's on-time's. Although a system of brushes to turn the coils on and off increases mechanical complexity and is more prone to failure, it does delimit the acceleration of the projectile. Additionally, it reduces the amount of calculation required for proper timing.

Prototype Case Design

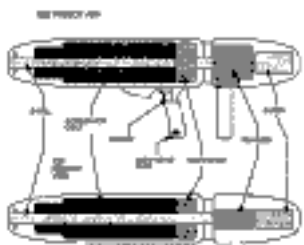
I worked on building a special case after the proof of concept for the Gauss Rifle. I wanted a case that was durable, flexible enough to bang around--or to change the configuration of the equipment inside of it, and large enough that I could move the positioning of the coils around without difficulty.

Although there are many options for building a case for a railgun/gauss rifle, I decided to go with variations on a layered composite resin case--which meant working with fiberglass. I actually worked both with fiberglass as well as the plaster-impregnated cloth material that's used for "instant" casts (the kind used on broken limbs). I found that although fiberglass alone was very strong as well as flexible, the plaster-based cast material provided more substance for mounting anchors to hold the internal equipment.



● Prototype Gauss Rifle

Using the knowledge that I had gained from the design of the railgun, especially with regard to coil temperatures and wire-tolerances, I began building prototypes for the Gauss Rifle. In the summer of 1994, I took about an entire week to spend building my prototype Gauss Rifle. Remember that the Gauss Rifle works simply in the same manner as a solenoid does--therefore, the physical construction is much easier than the railgun.



Because of availability problems for some of the sophisticated parts required for the project, I decided to build a scaled down model to prove the theory. I used the 50 caliber steel bearings as projectiles still, however, the propulsion system for them used a substantially reduced coil in addition to using a combination battery/capacitor system to charge to coil. I experience moderate success with the Gauss Rifle--even using only a one stage design. Unfortunately, I attempted to push the coil beyond the limits of my design tolerances, which means that it melted when I pushed the power up too high. Therefore, the theory was proved--at the expense of a week's work. The projectile did fly across the room that I was in, which is to be about the expected propulsion to be had from a one-stage system pushing a projectile that is far too large for the propulsion unit.

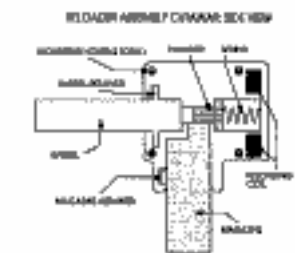


● Gauss Rifle Physics

The Gauss Rifle uses the same principle as a common solenoid to cause the attraction of a ferro-magnetic projectile to an electromagnet situated at a distance down the barrel of the weapon.



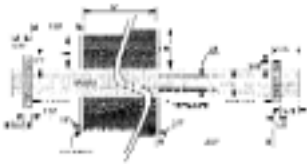
The solenoid works on the principle that iron--or ferrous--materials are attracted to magnetic fields. By created a very large artificial field and attracting the projectile down the barrel towards the field, the Gauss Rifle accelerates the projectile up to speed. Once the projectile has reached the proper position, the timing mechanism in the Gauss Rifle shuts the field off and the projectile continues on down the length of the barrel at high velocity.



An extension of the Gauss Rifle accelerator uses multiple coils at different distances down the length of the barrel, which turn on and then off in a linear series to increase the acceleration of the projectile.

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Simplified Accelerator Rail Gun



● Gauss Rifle Cutaways

I experimented with several options for some of the gauss rifle features, including more sophisticated modular components than were included in the design for the railgun.

In the top picture, the barrel and coil positioning is shown for the gauss rifle--as you can see this portion of the design is greatly simplified compared to the original railgun design. This was partially so that I could experiment a little more with the barrel without having to completely disassemble the accelerator, as well as allowing me to have a little margin to correctly position the coil down the length of the barrel.

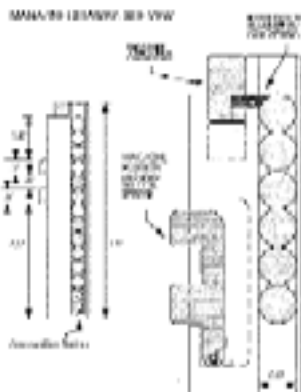
The reloader takes a bottom-loaded magazine similar to those found in many conventional weapons. The interior of the reloader is configured to bolt together as two halves over the barrel, and contains a chamber in the right portion of the graphic to house the spring-loaded ammunition plunger, which positions the ammunition through the firing cycle.

● Circuit Layout

The bottom graphic shows one of the many circuit designs that I considered for the gauss rifle's operational circuitry. The design that I installed in the prototype was somewhat similar to this diagram. Notice the parallel arrangement of MOSFET power transistors--the commercial components that I designed with couldn't handle the amperage for the required amperage load, so I had to stack them in parallel. Transistor Q6, which is sitting all by itself, is actually only used to power the reloading plunger, and doesn't require much current.

Also notice the layout of the coils--although the current flows to the coils in a common bus, the coils are separated into a parallel arrangement--this allows the use of shorter lengths of higher gauge magnet wire to reduce size and overall weight, with a higher overall amperage. The coils are driven in unison--this circuit design does not incorporate a series-driven coil arrangement, and the coils were wound too close together to allow a series array.

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● Gauss Rifle Magazine

The magazine is a critical part of the gauss rifle design, in that for a production design it would have to be inexpensive to produce in mass quantities, able to be dropped, soiled, and still remain functional, as well as hold the ammunition securely when not in use. At the same time, the magazine is required to assist loading the ammunition into the chamber during firing repeatedly without error and at whatever speed the weapon may require it.

● Integrated Handle

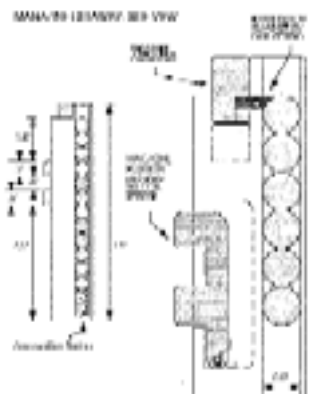
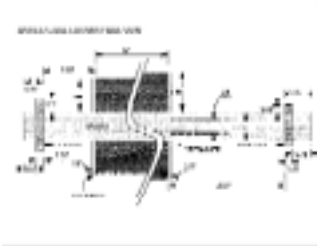
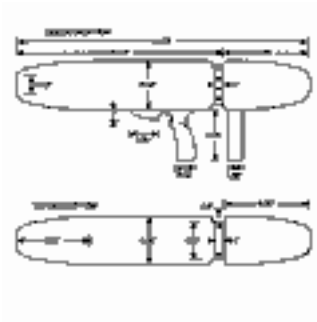
The handle for the gauss rifle is just an approximation of the one that I constructed from fiberglass for my prototype gauss rifle. A production version would be integrated as part of the chassis design, and would probably be molded in halves along the chassis centerline, for easier assembly.

The handle contains the trigger mechanism, which would simply be a normal pressure-switch, as well as the safety mechanism--in my design another switch located in a thumb mount position to require full handle grip before firing.

The handle would not contain the magazine, primarily because the ammunition at 50 caliber would makes the magazine too large to fit into an ergonomically sized handle.



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● [Magnetic Weapons Information](#)

Introduction to what magnetic weapons are, how they work, and government and private resources and research. Also defines the distinction between a railgun and a gauss rifle in terms of operation and performance.

● [General Project Overview](#)

Outlines the beginnings of my research into railguns and gauss rifles, as well as the design goals that I used during the creation and testing of my designs.

● [Project Success Achievement](#)

Outlines the success and failure of my railgun and gauss rifle design and subsequent testing. Covers some of the strong and weak areas of my designs, and improvements to address these areas.

● [Prototype Railgun](#)

Overall and cutaway views of my prototype railgun, including working details on case design, layout, and coil positioning.

● [Railgun Accelerator](#)

Overview and cutaway views of the main railgun accelerator, and the dimensions and accelerator layout schematics.

● [Railgun Magazine Features](#)

Features of the rotary magazine that I designed into the railgun for fast operation and high volume. Cutaways and operational schematics.

● [Railgun Parts and Circuits](#)

Details on some of the other additional parts that I designed for the railgun, as well as circuit schematics for the accelerator electronics.

Prototype Gauss Rifle

Overview and case design schematics for the gauss rifle, including case dimensions, equipment layout, and the reloader assembly.

Gauss Rifle Components

Cutaway views and information for the reloader and main accelerator coil designs, as well as circuit overviews for the accelerator.

Gauss Rifle Magazine / Handle

Design notes and cutaways for the gauss rifle magazine and integrated handle, as well as physics notes on a preliminary design.

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Do not work with chemicals, fiberglass material, or any other toxic chemicals without proper training and equipment.

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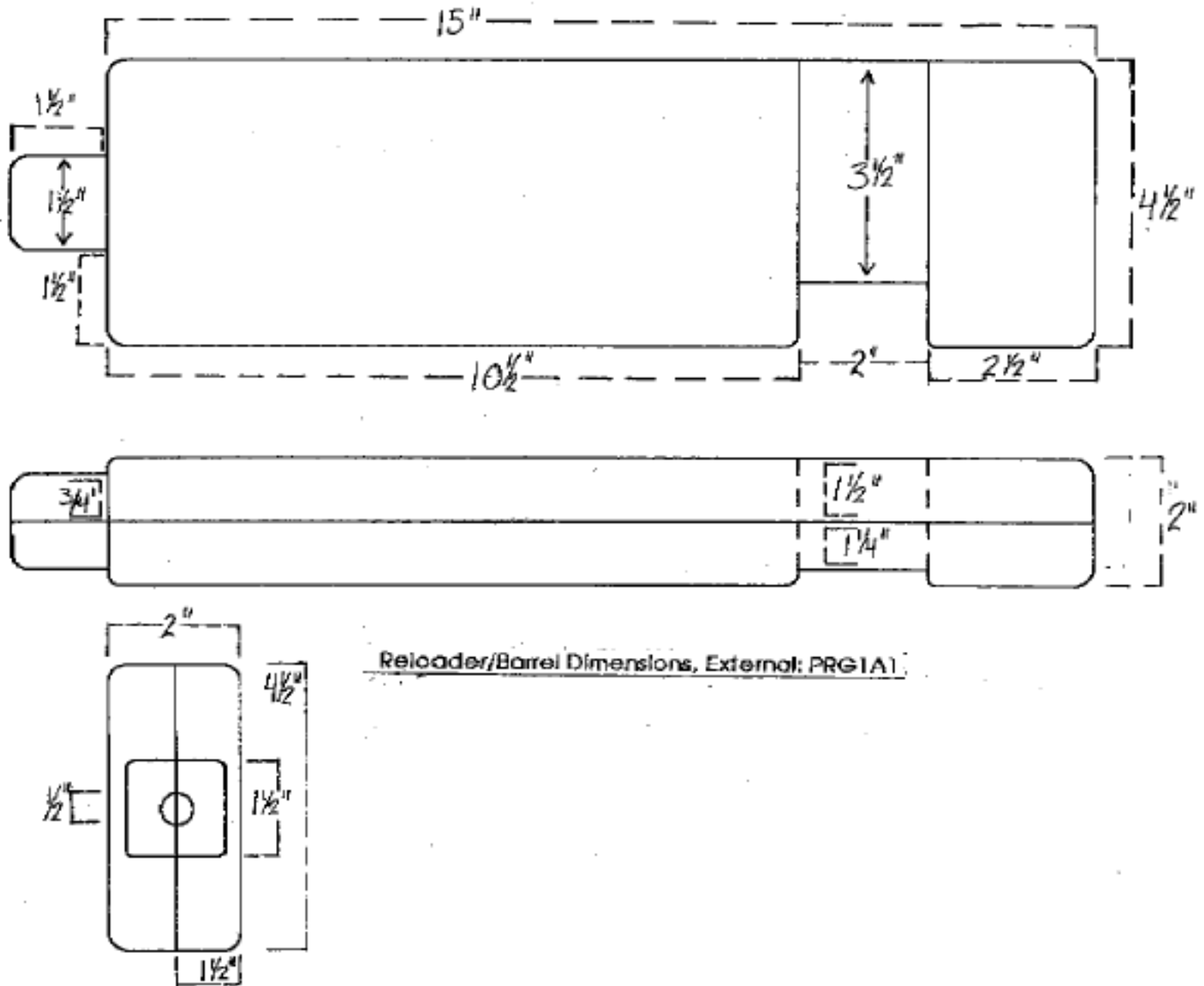
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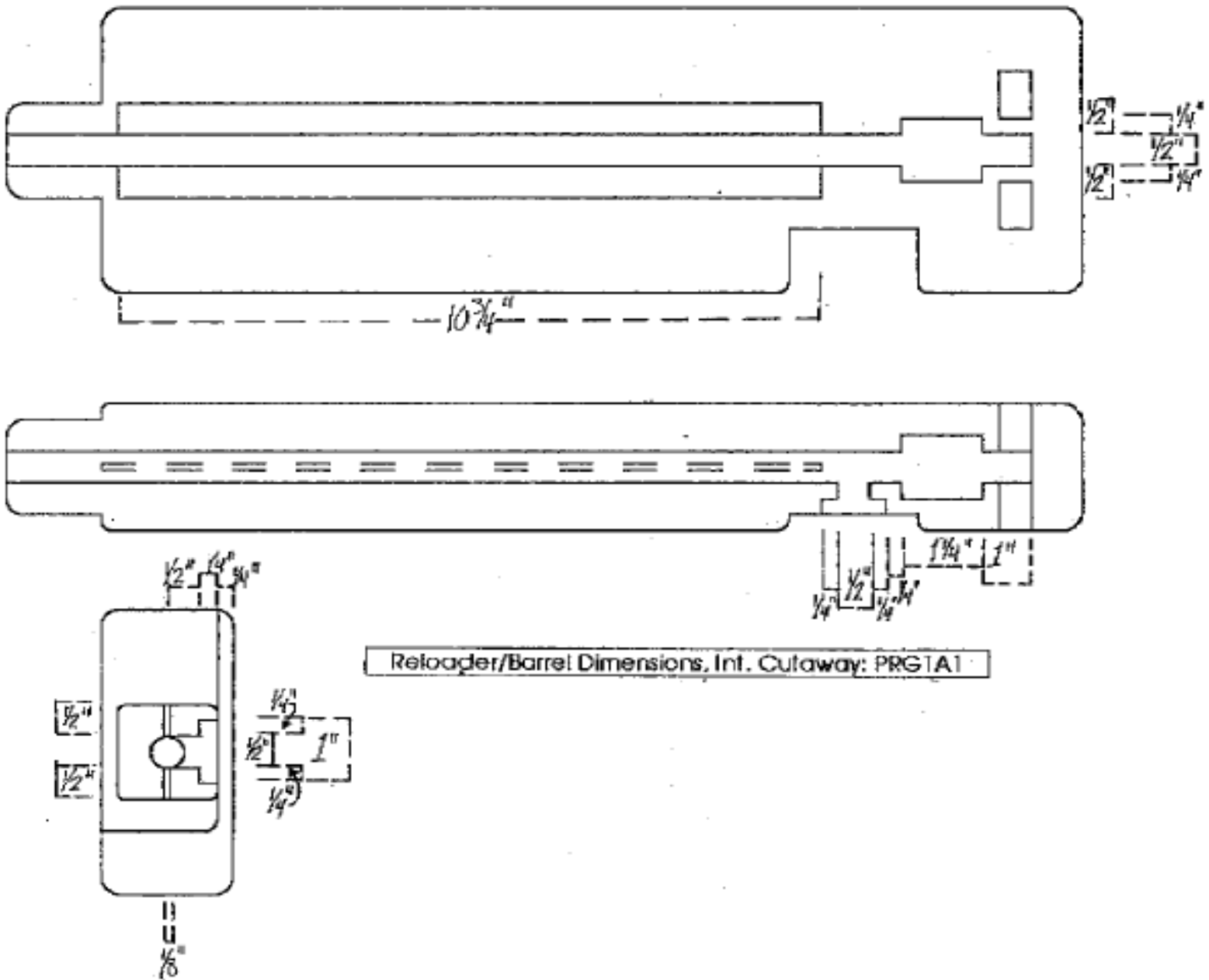
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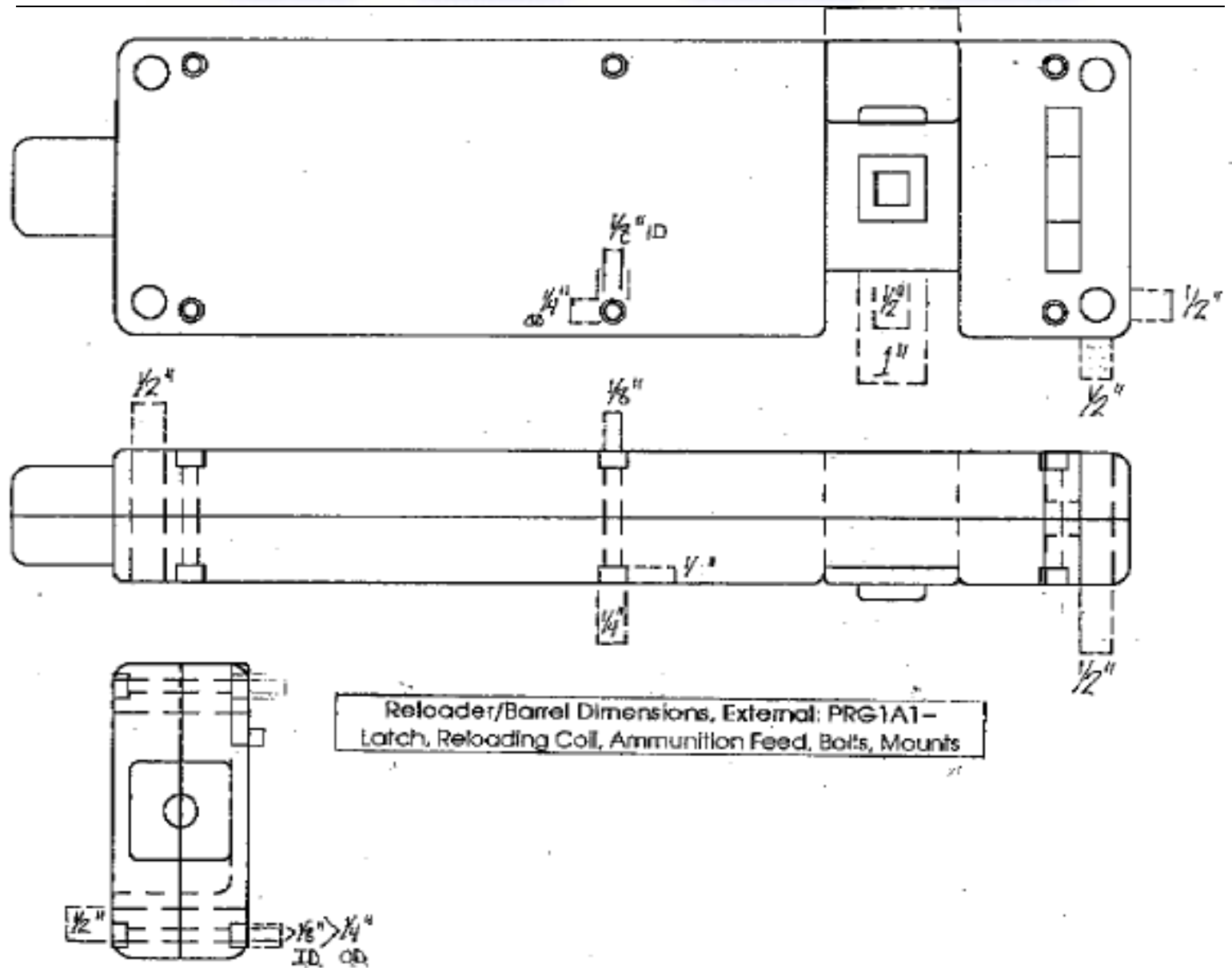
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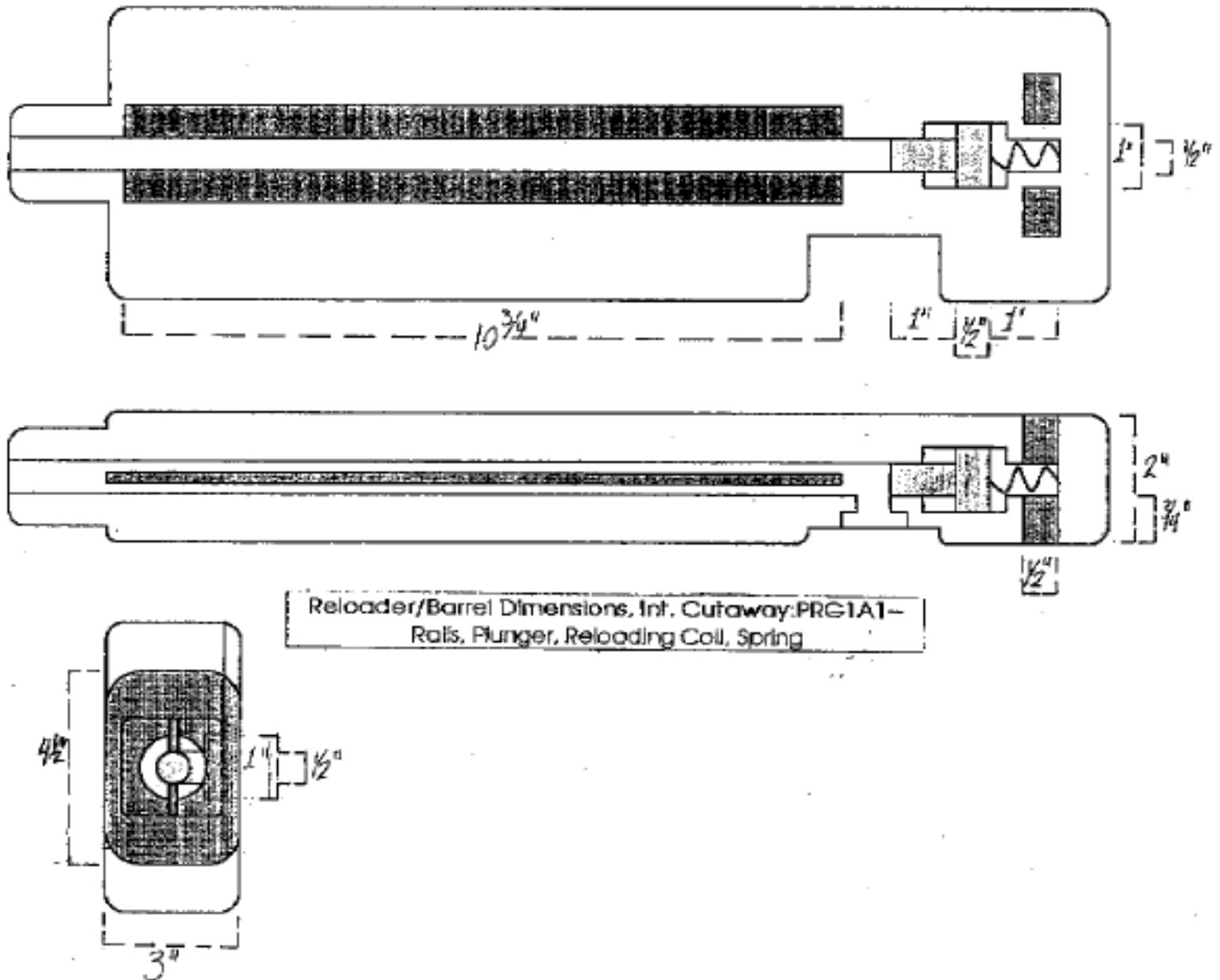
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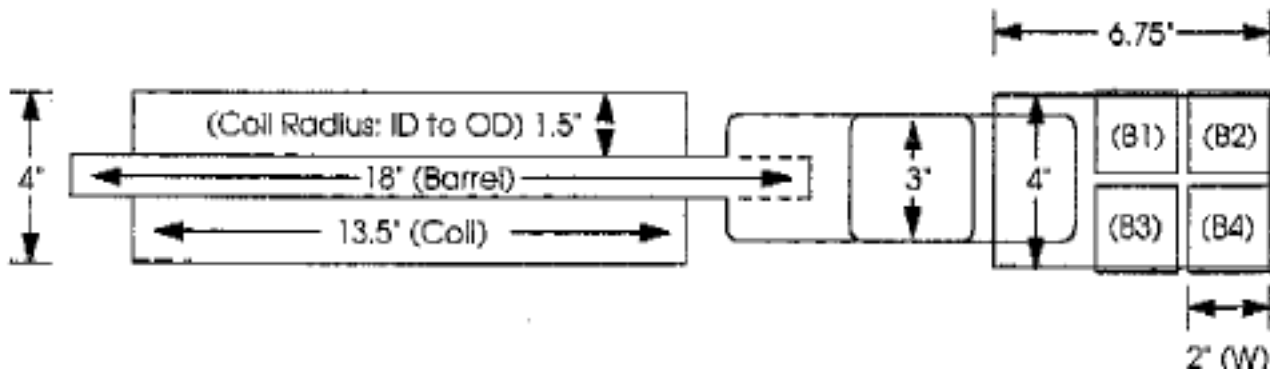
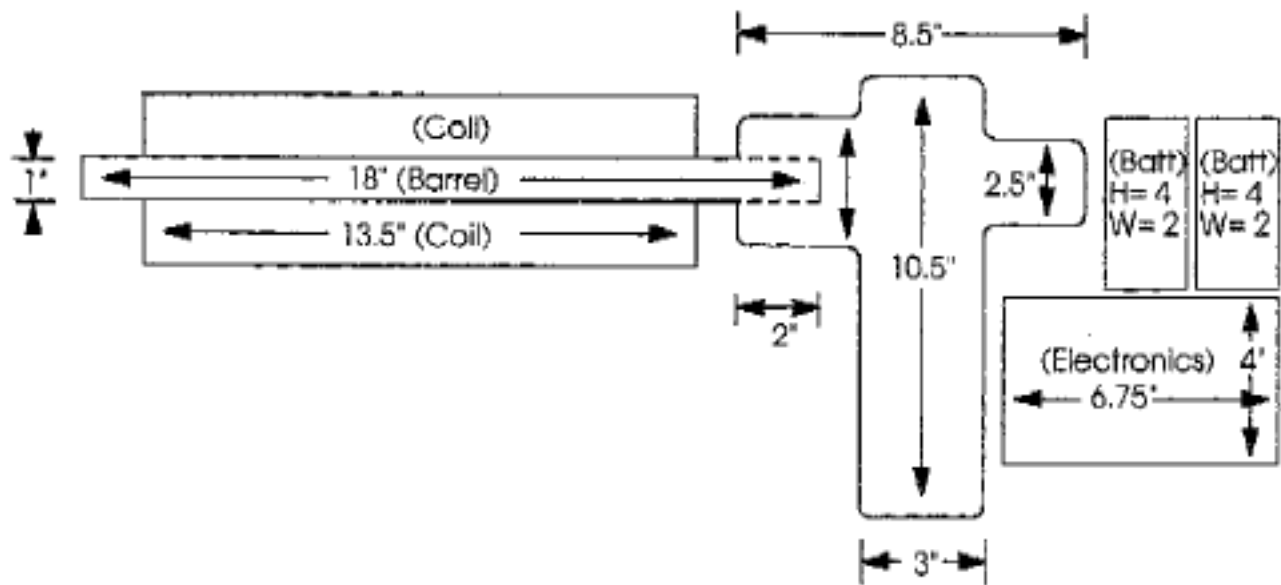
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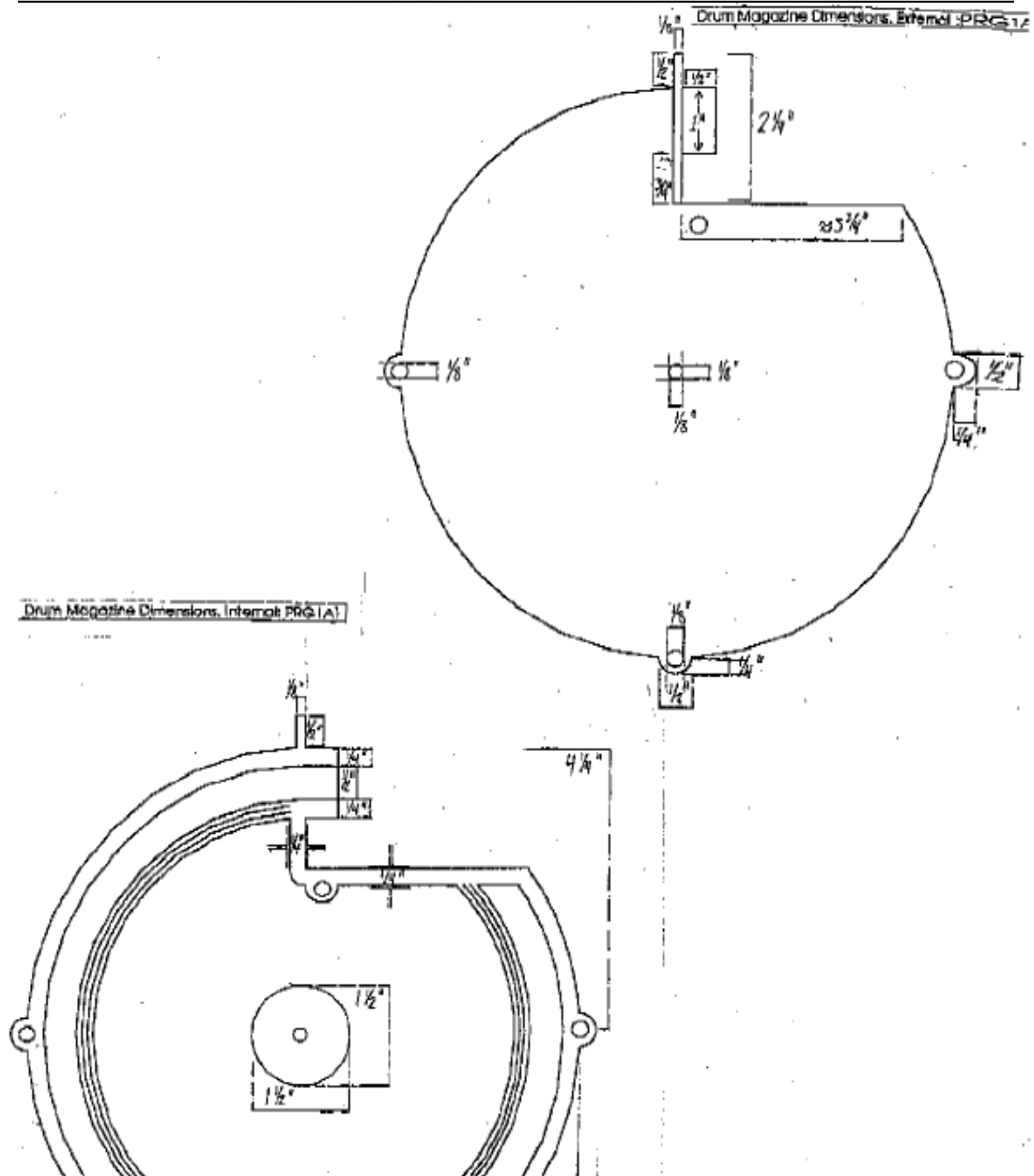
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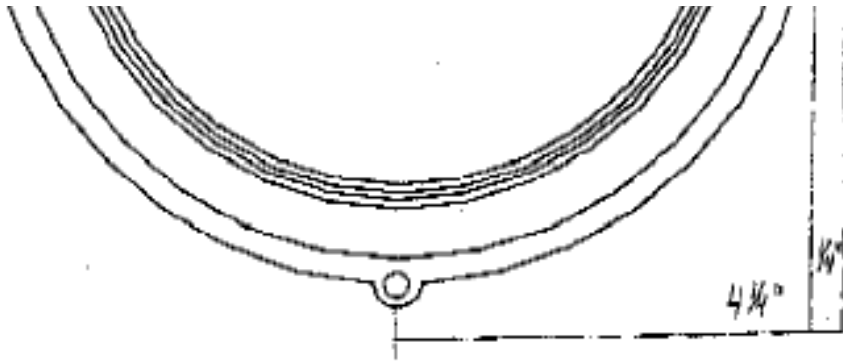


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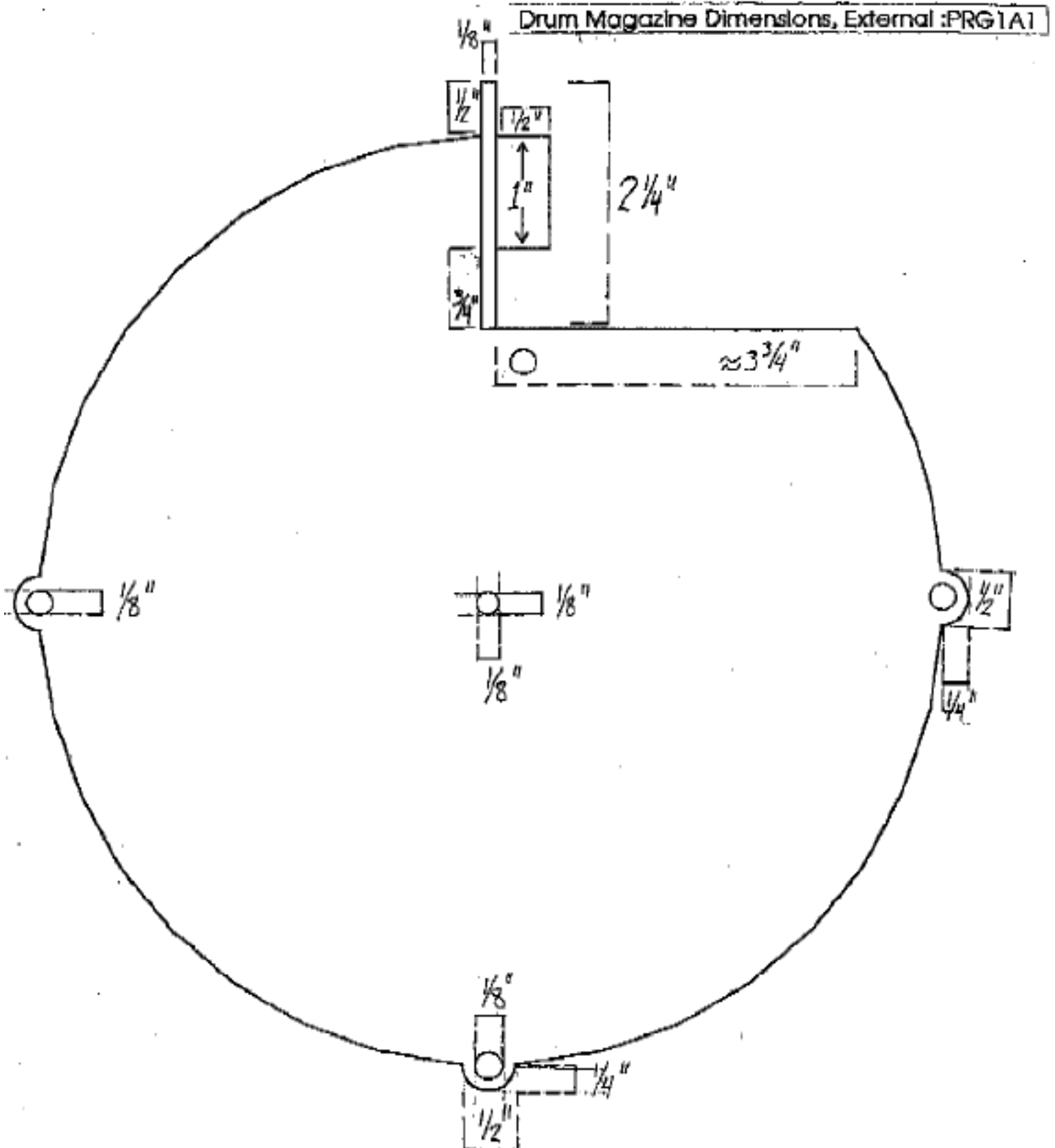




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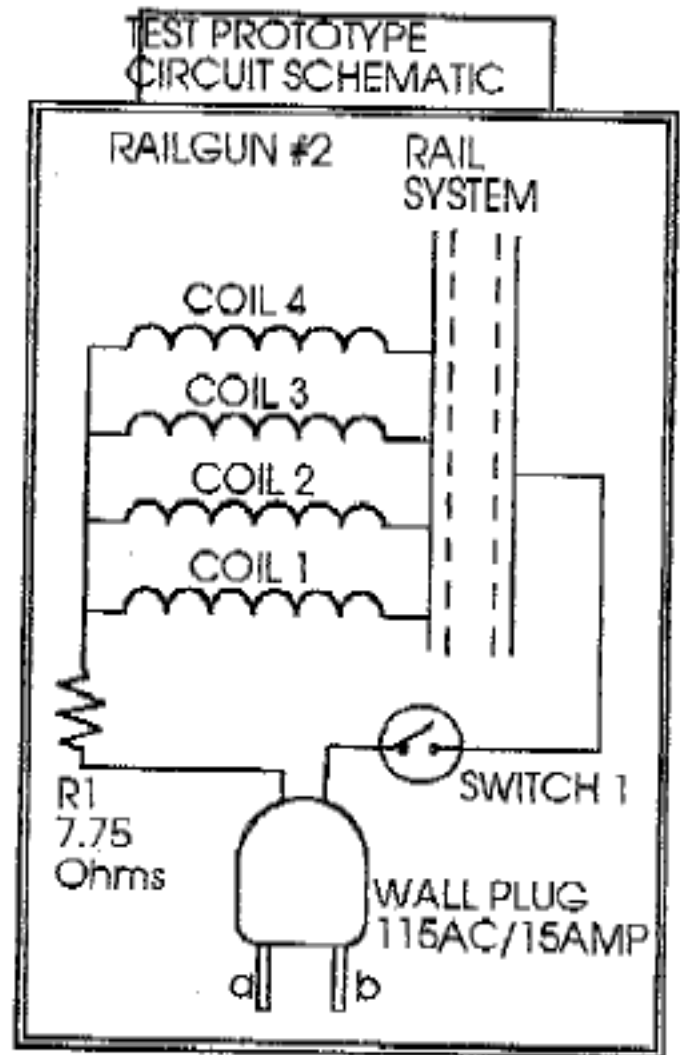
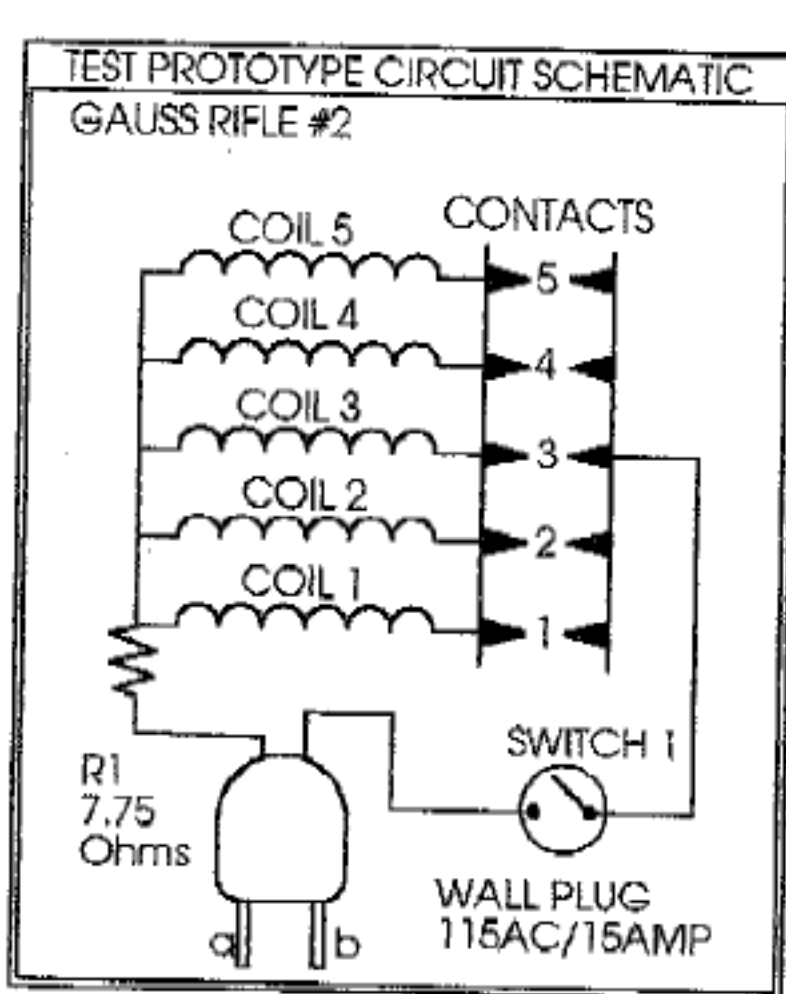
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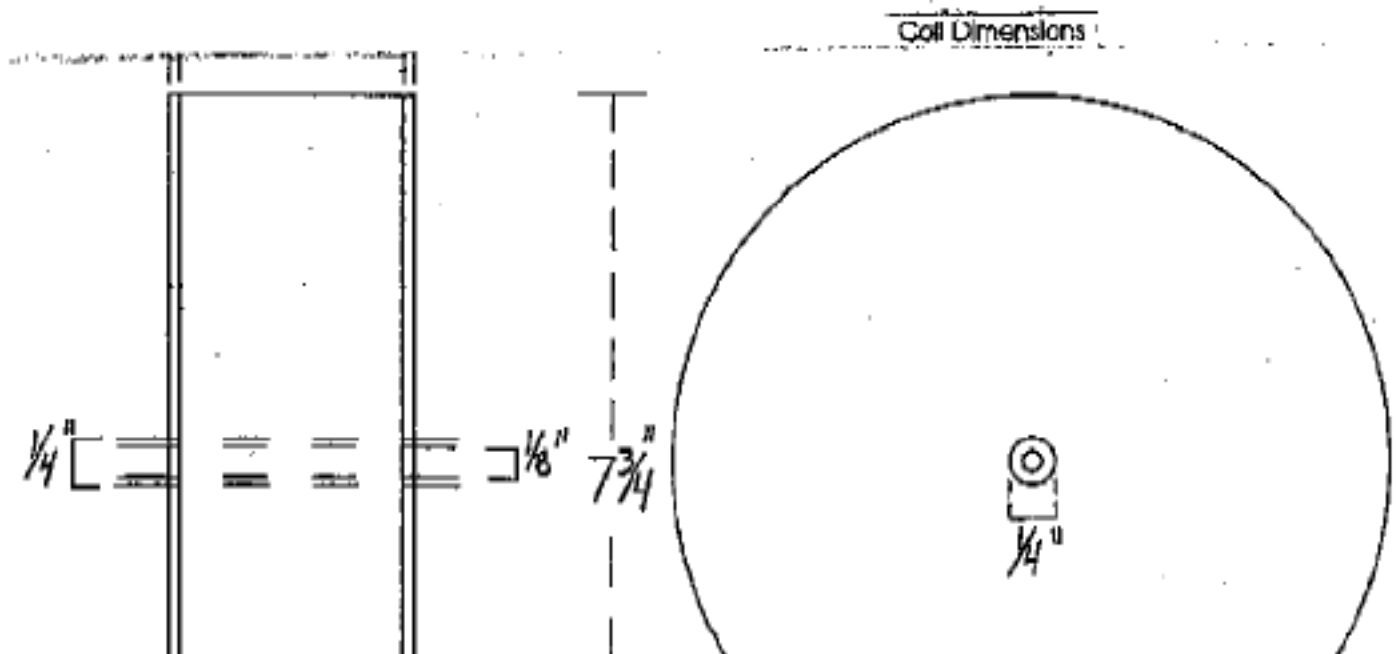
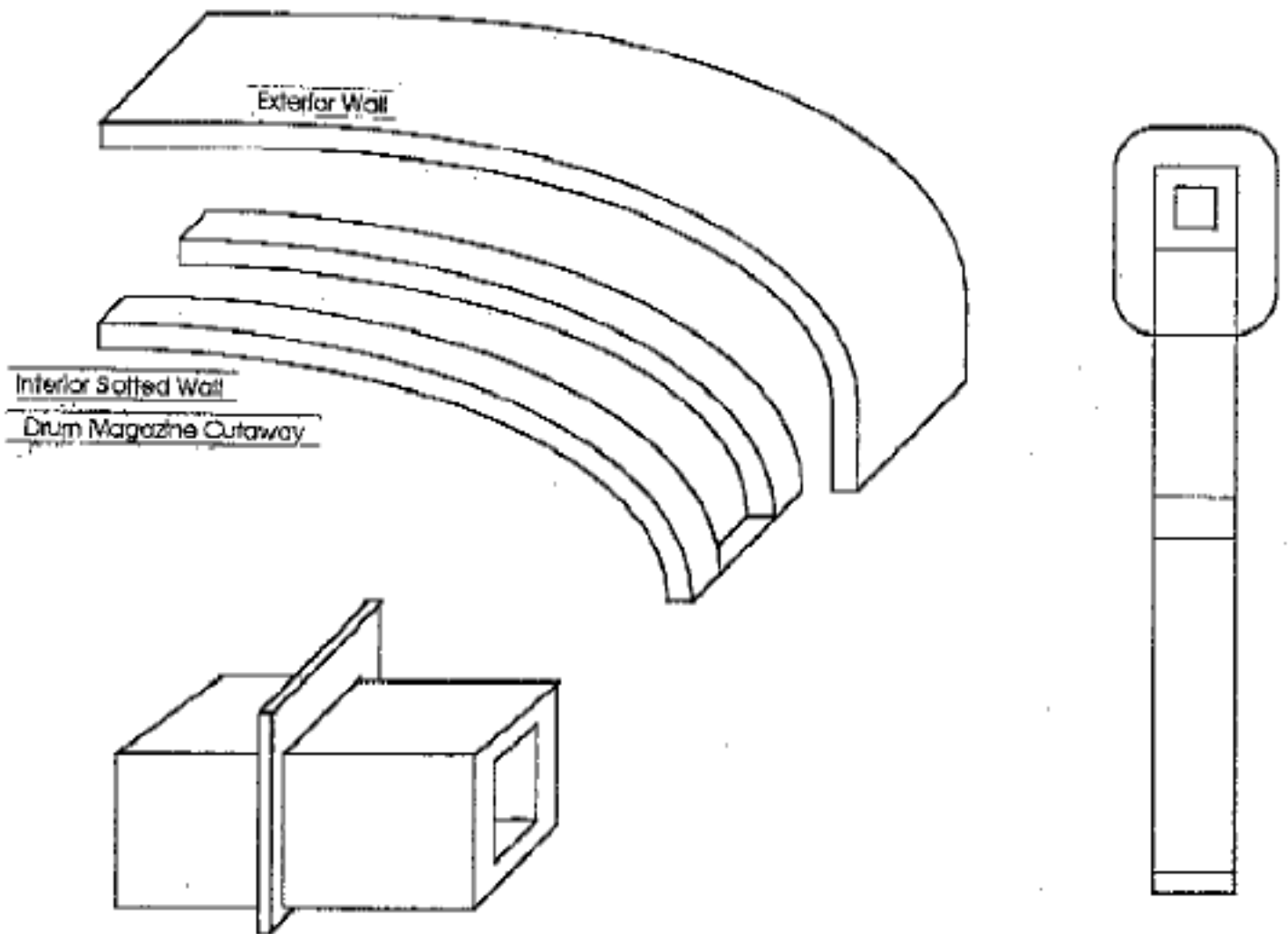
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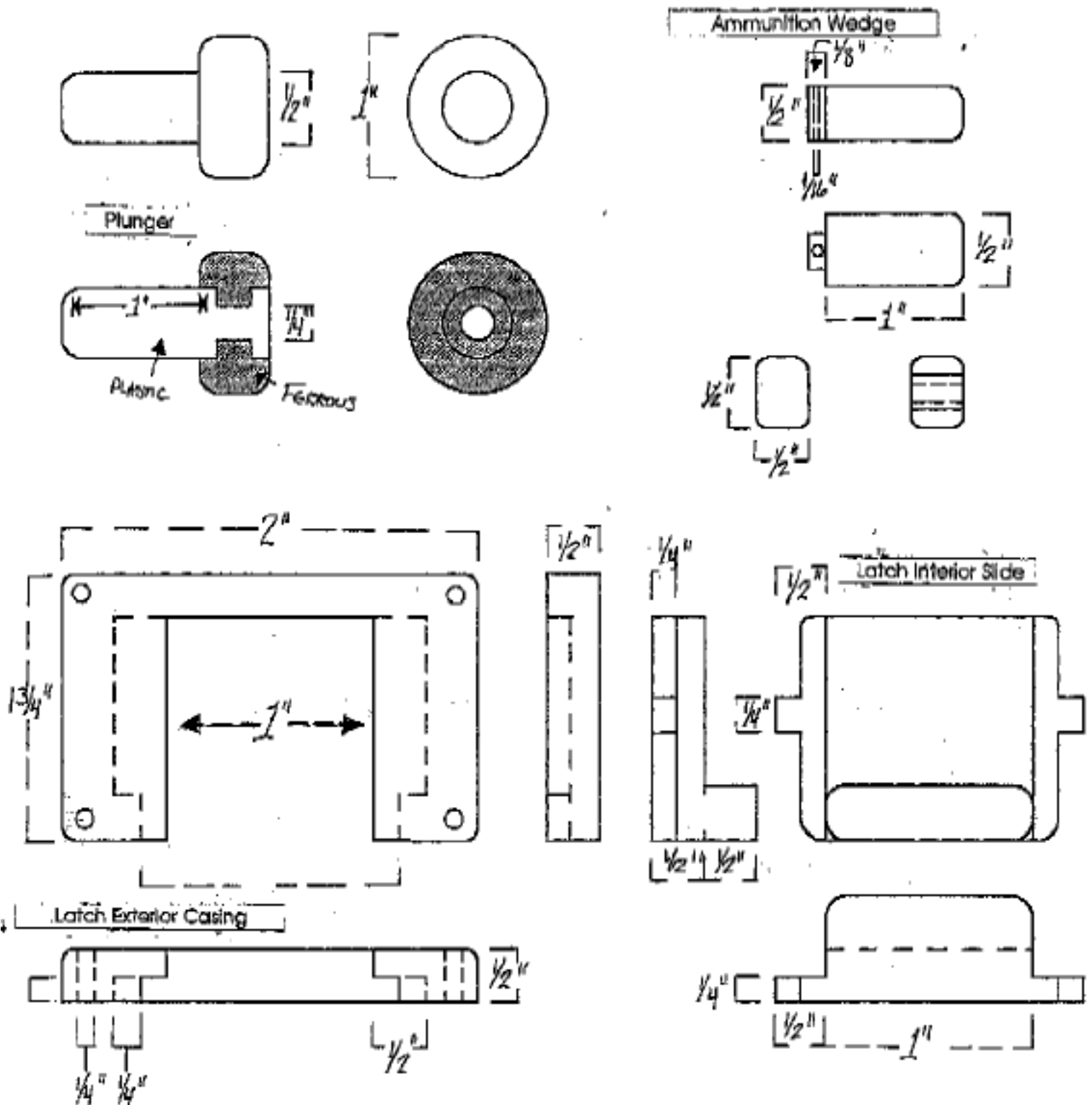




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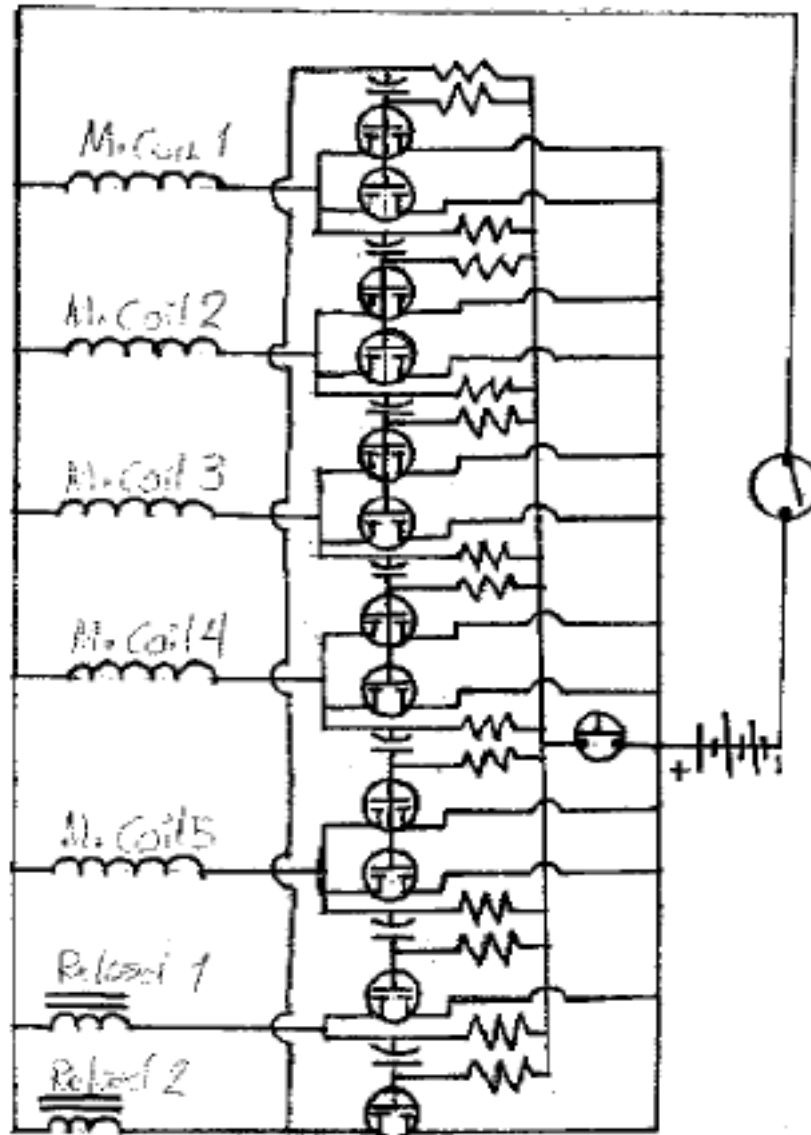
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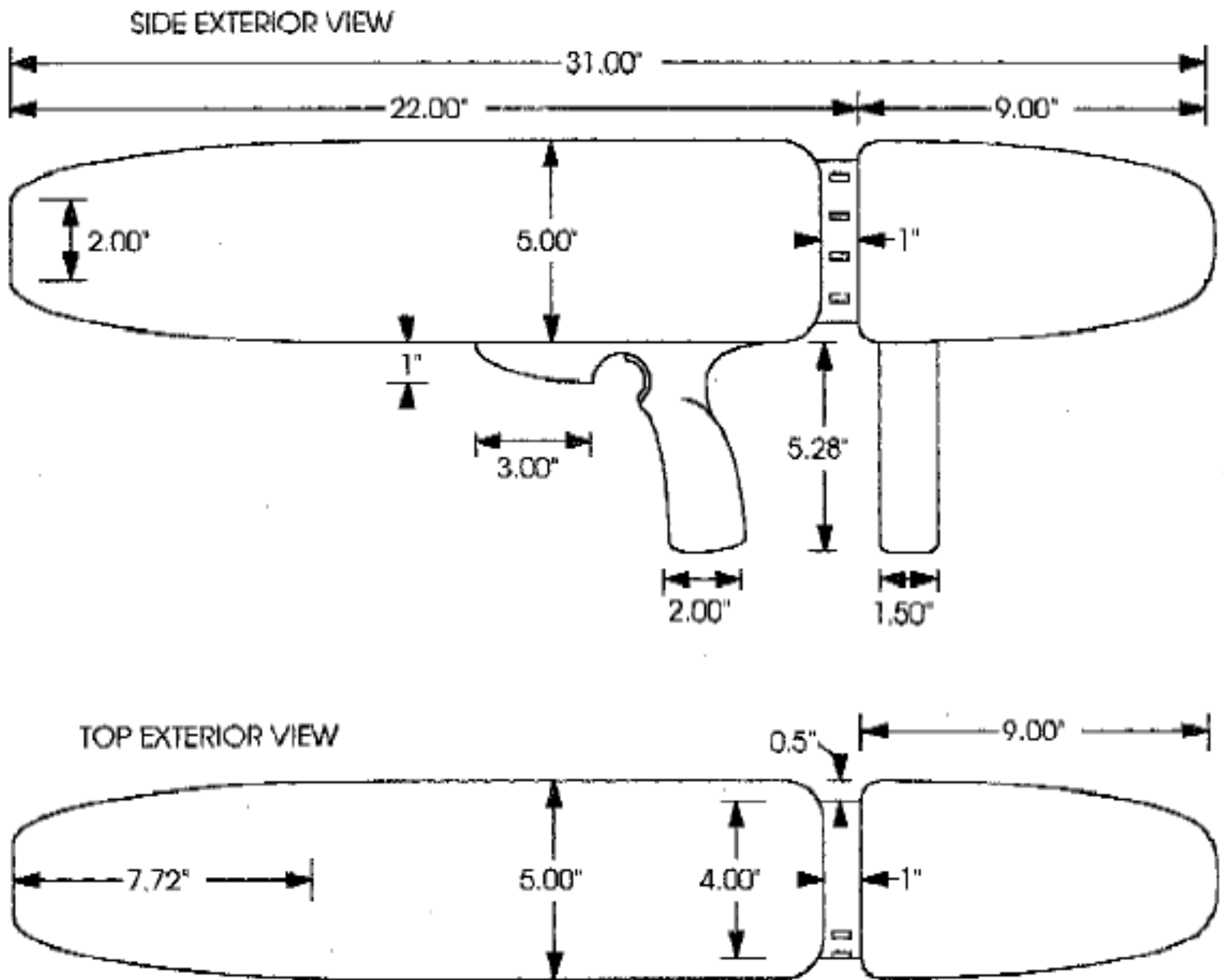
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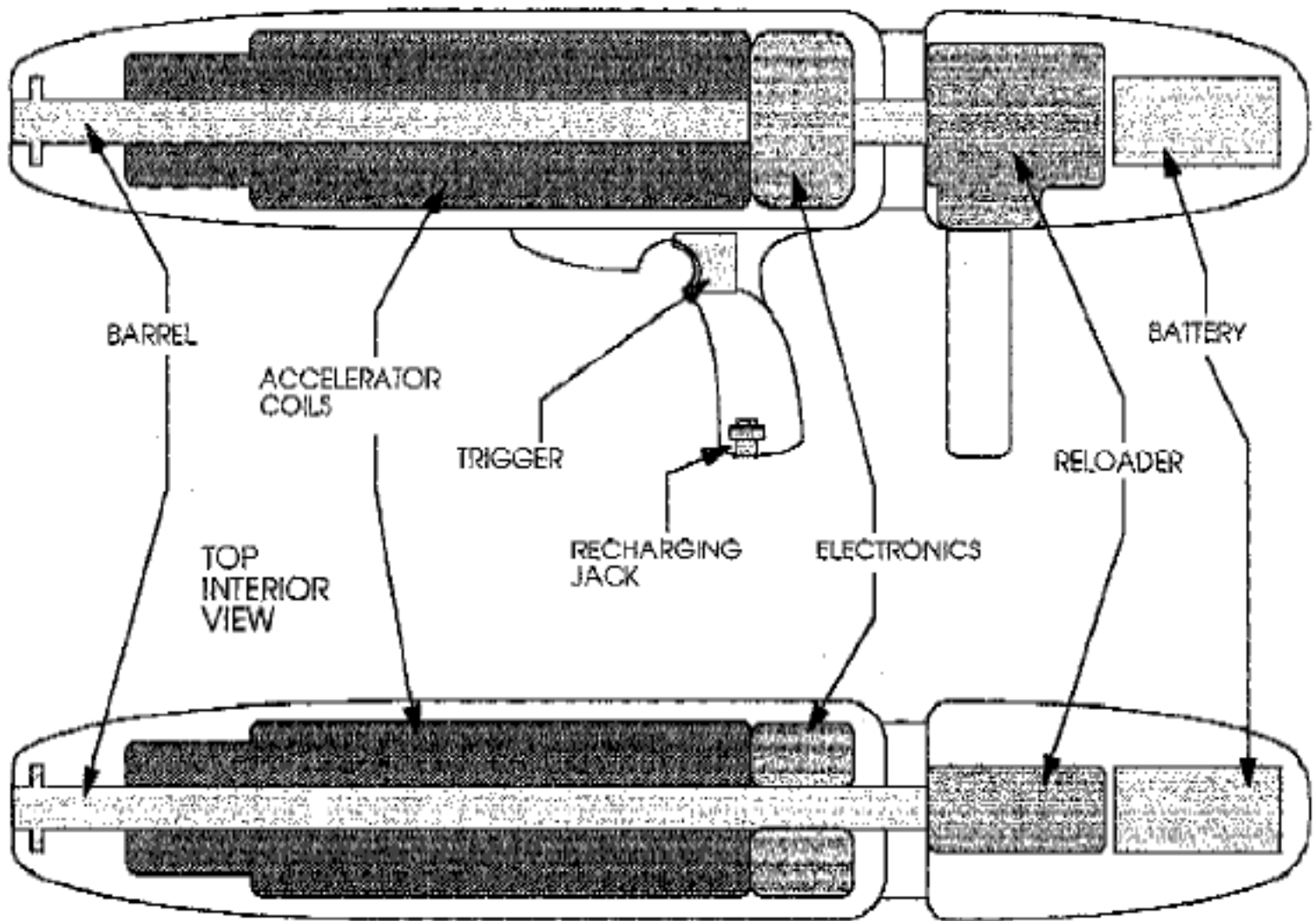


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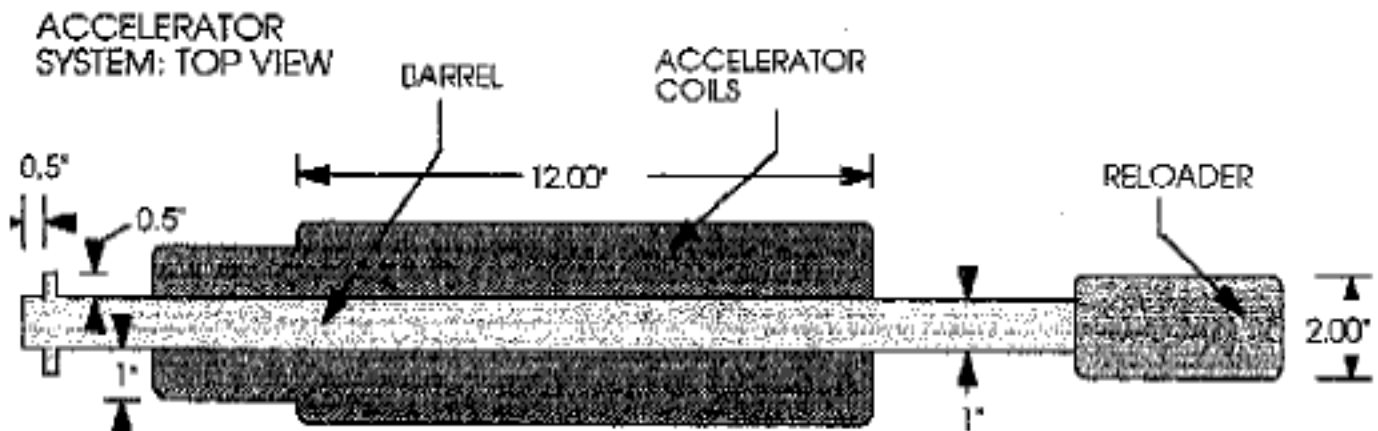
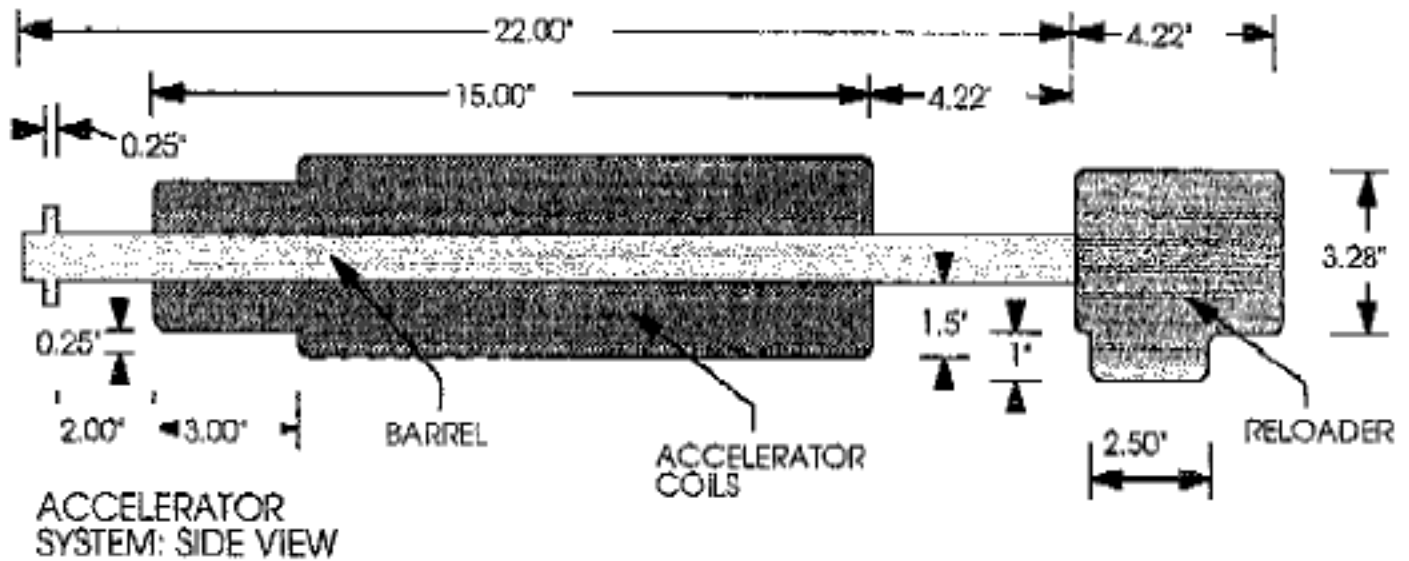
SIDE INTERIOR VIEW



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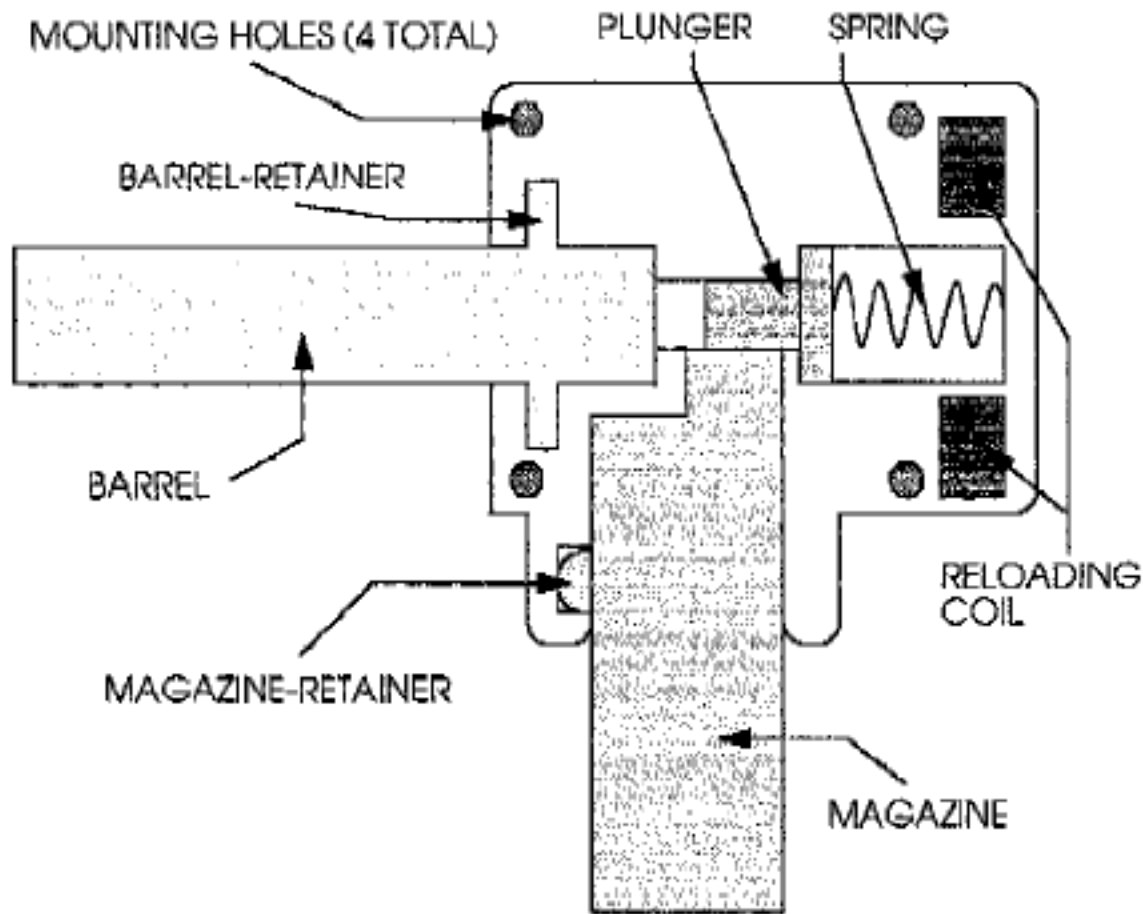


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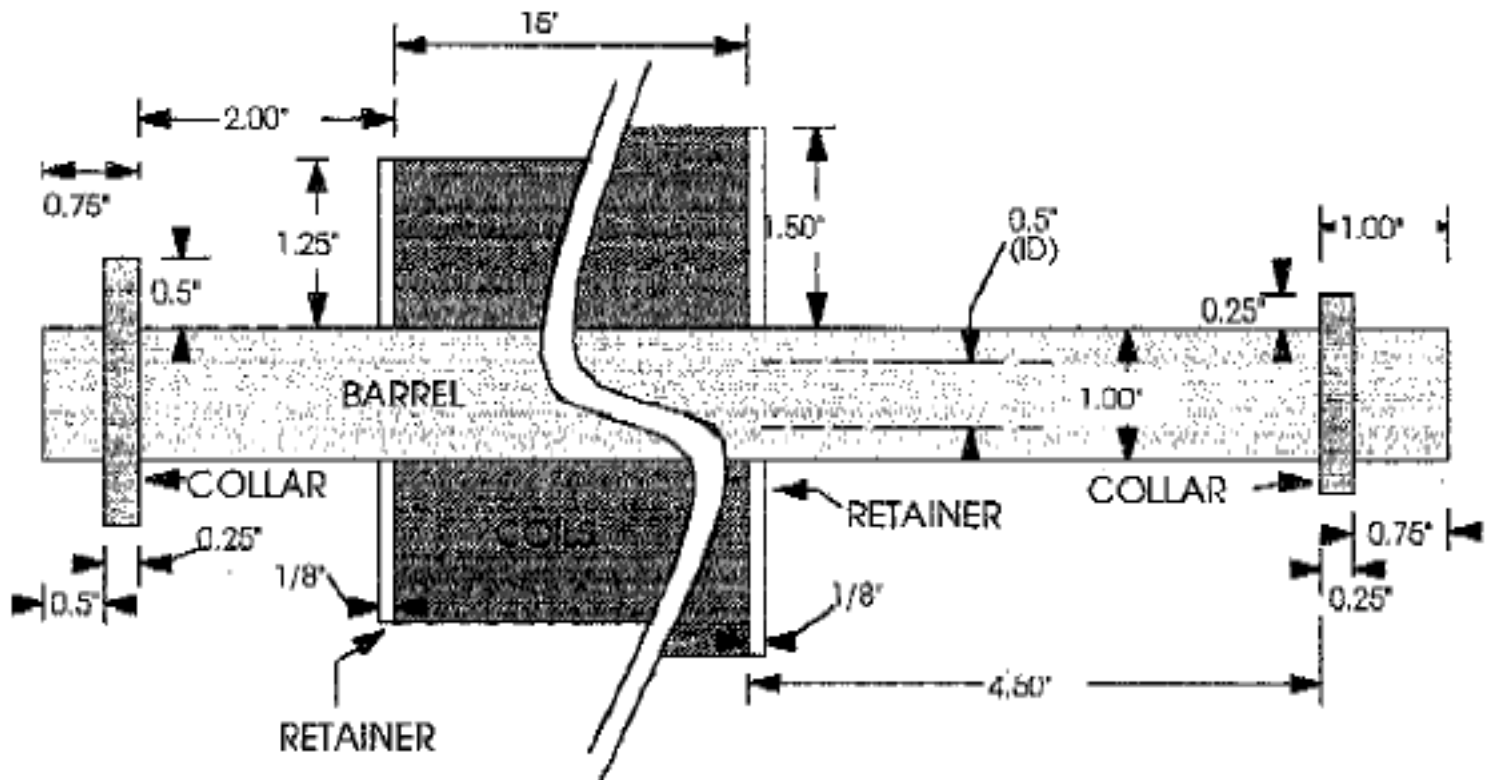


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BARREL/COILS CUTAWAY SIDE VIEW



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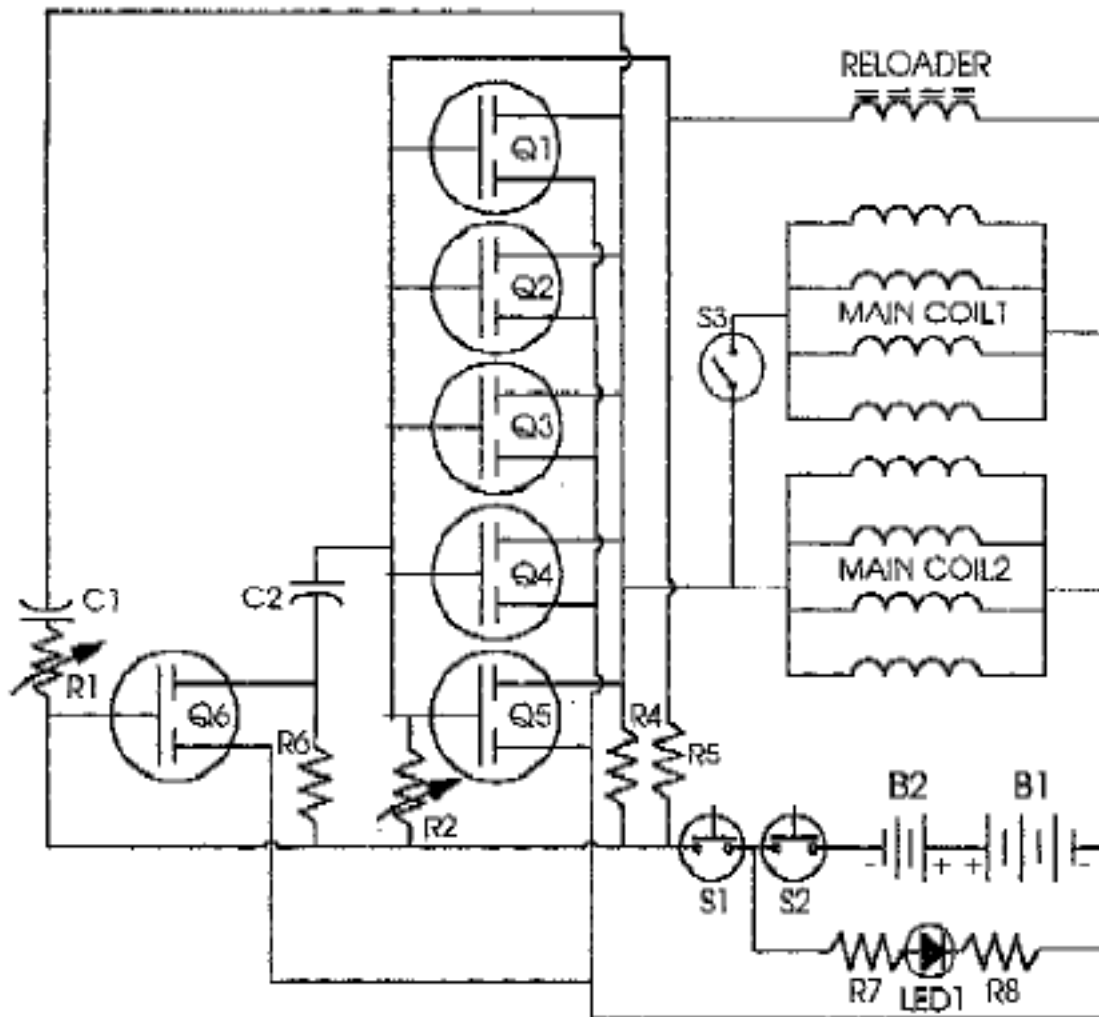


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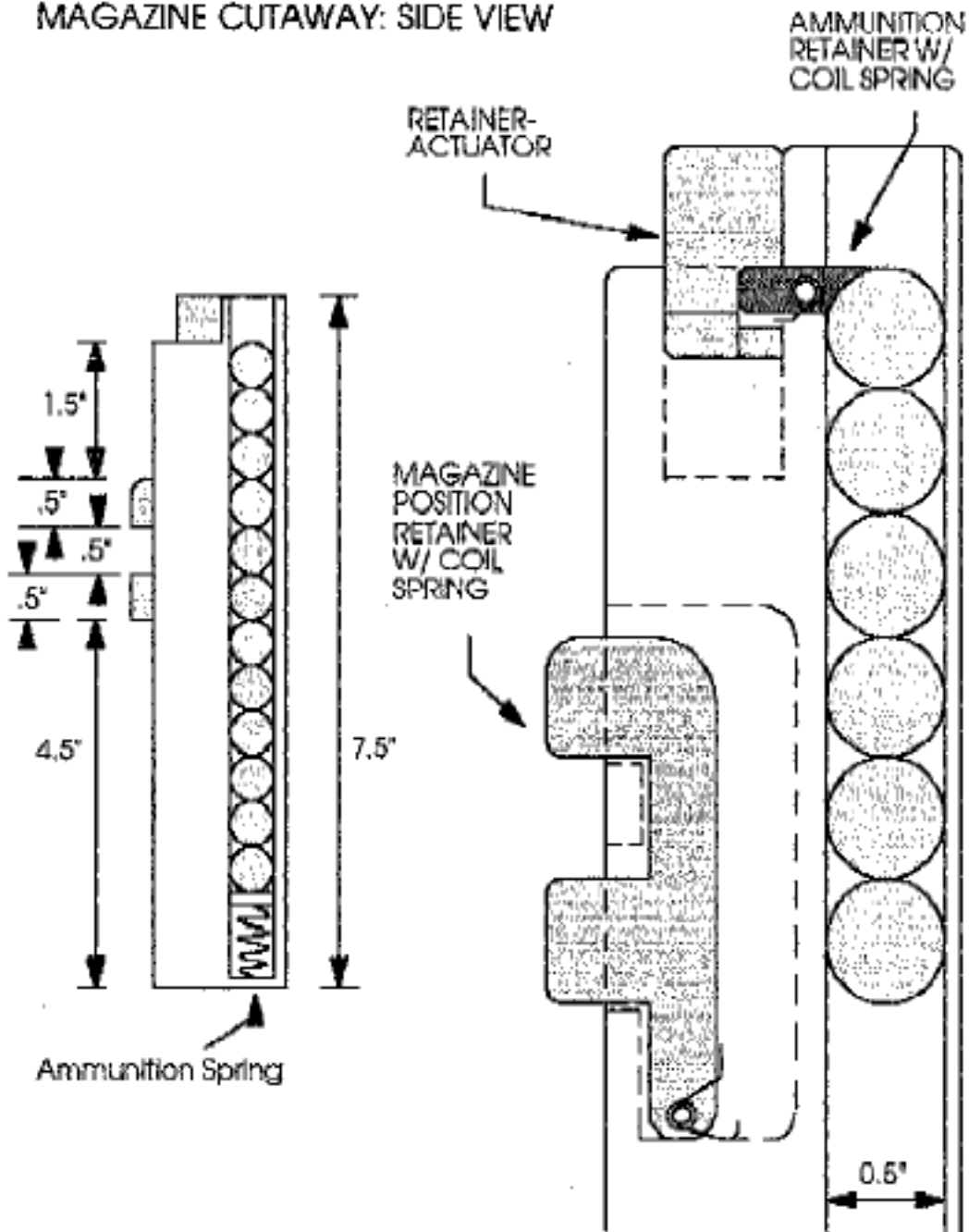


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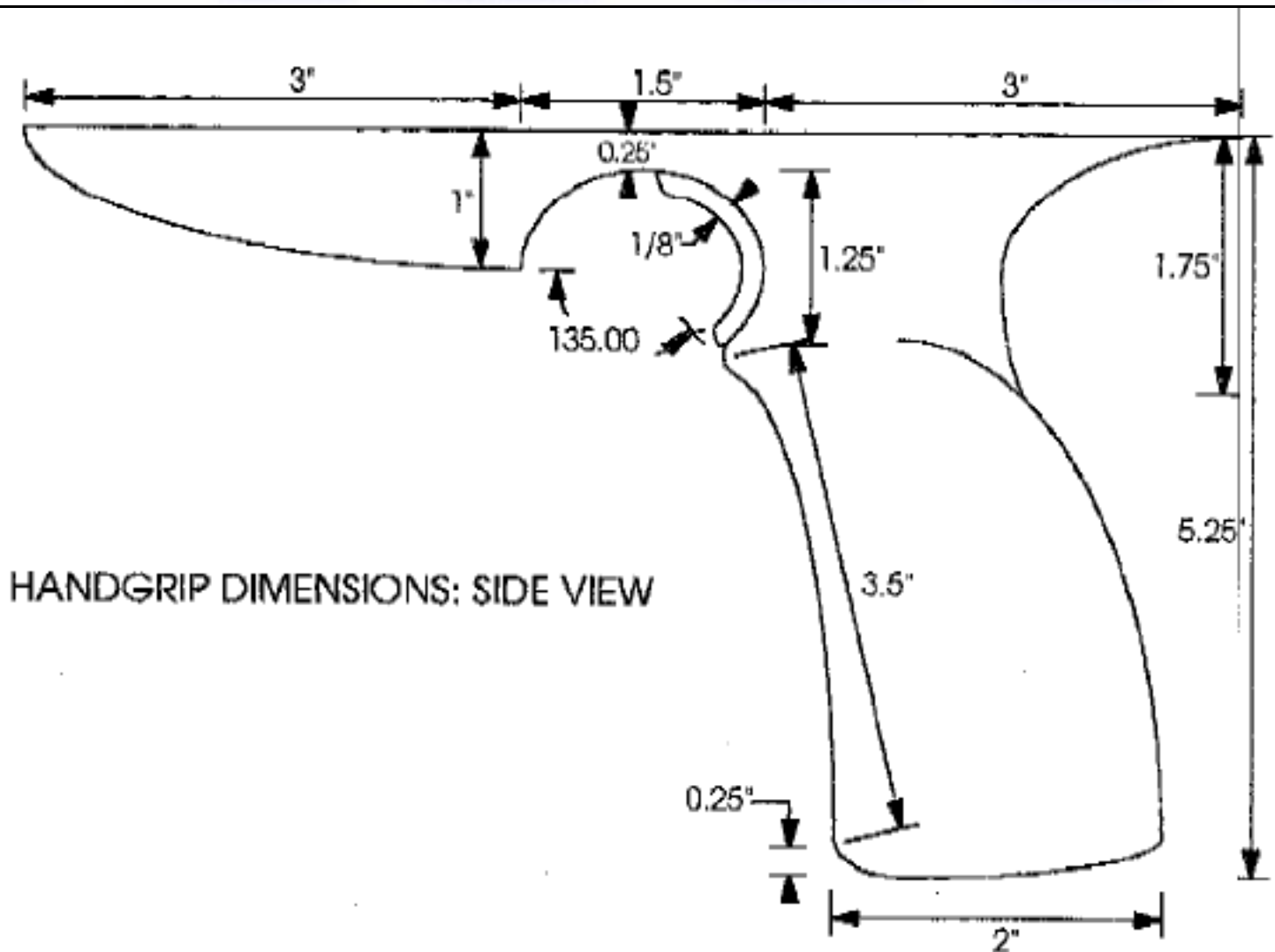
MAGAZINE CUTAWAY: SIDE VIEW



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RAILGUN DESIGNS

PRG1A1 RAILGUN

COIL HEIGHT: 6.5" (162m) total Cross Sectional Coil Area:
 Avg. Circumference: ~~5.8875~~ 5.8875 inches
 Projectile - DIAM: 0.0127 m (1/2") ; WEIGHT: 0.00773325 kg.
 Total Turns: 9300 Turns_H: 100 Turns_w: 93
 Total Wire Length: ~~4,557.4~~ 4,557.4 / Total R: 29.660 Ω

Sub-Coils: 8 # Turns each: 1162.5
 Turns_H each: 13 Turns_w each: 93 turns
 Resistance each: 3.7082 Ω Length each: 569.625 feet
 Wire Resistance: 6.51 Ohms / 1000 feet
 Current, Ex: 323.607 Amps / Current, Total: 2,588 Amps
 A·T = 3,010,839.528
 A·T/m = 18,585,429.19
 Flux Density = 197.924
 Force = 6505.286 Newtons
 Converted = 2,801.229 f/s

Full Supersonic

Subsonic

Subcoils used: 4 Current: 1294.428 Amps
 AT = 1,505,419.764
 AT/m = 9,292,714.593
 Flux Density = 98.962 W/m²
 Force = 1626.867 Newtons
 Converted = 700.542 f/s

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RAILGUN DESIGNS

Railgun Design #2.3: Fully Automatic

Projectile : $\frac{1}{2}$ " (.0127m) diameter sphere, (.50 caliber)
 Weight: 0.275 ounces, .00773325 kg.

Velocity: 1,750 Feet/second (574.146 m/s)

Barrel: 2 ft. length (0.65616 m)

Projectile Time to transverse barrel at maximum velocity: .0011428 ^{used (.001s)}

Coil Comp: Copper Insulated Magnet Wire, 16 Gauge ^{used (.001s)} Coils
 (15.64 lbs.) 2000 feet @ 8.18 Ohms or (nominal 950 turns)
 (11.73 lbs.) 1500 feet @ 6.135 Ohms (nominal 715 turns)

Coil Dimensions: Length: 2.05 ft. (0.67257 m) (adjusted)
 Width: 0.625 in. (1.5 cm) (adjusted)
 Height: 0.3937 in. (1 cm) (adjusted)

F_N : necessary 2,220 Newtons total (exact 2220.011073 N)
 444N

~~$$F = B \cdot L \cdot I$$~~

~~$$2,220 = B \cdot I \cdot 0.0127$$~~

~~$$174,804.0215 = B \cdot I$$~~

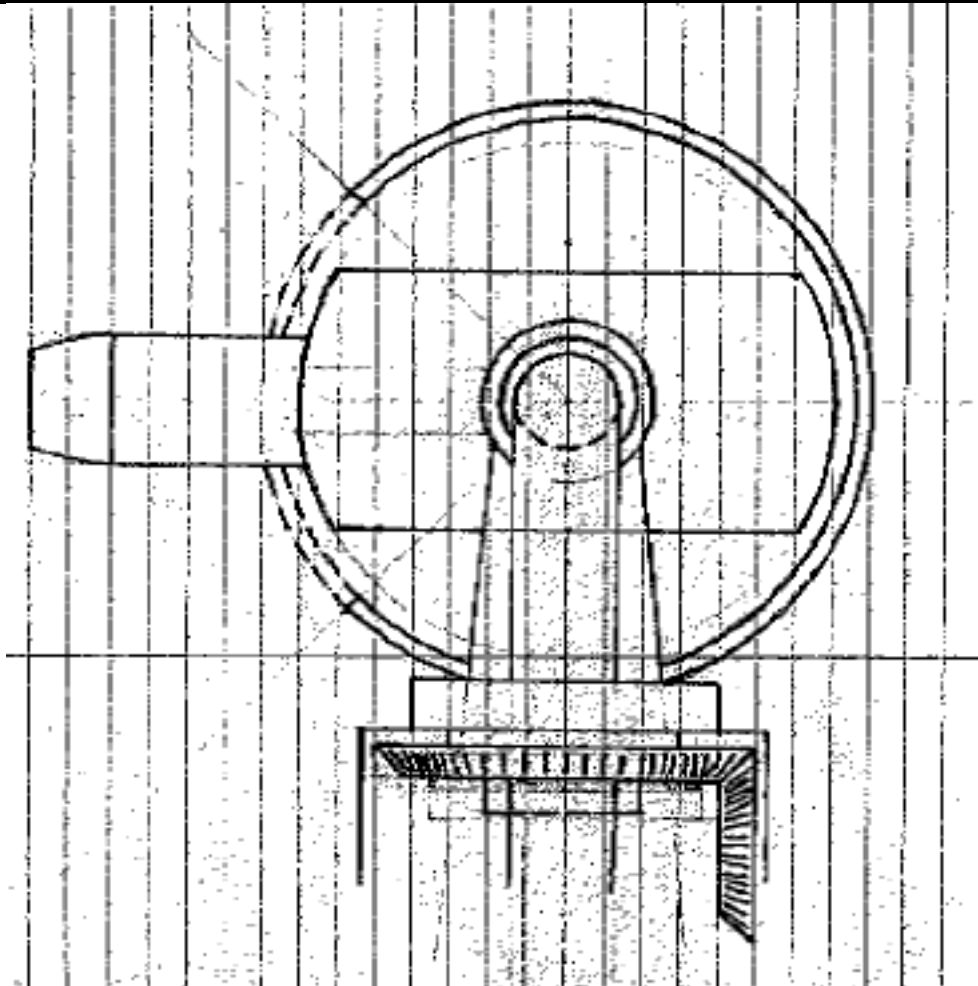
$$F = B \cdot L \cdot I$$

$$F = B \cdot I \cdot 0.0127$$

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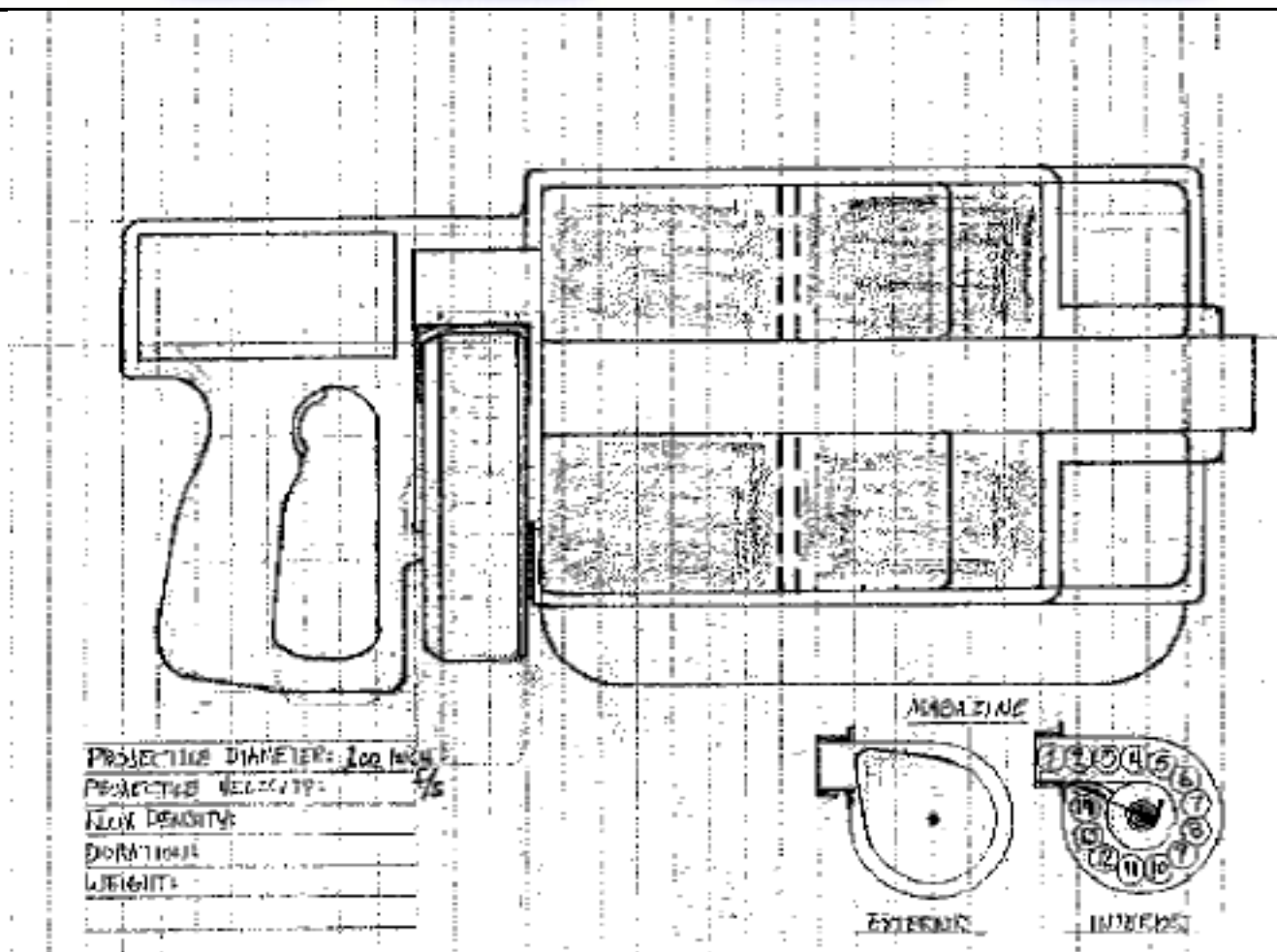


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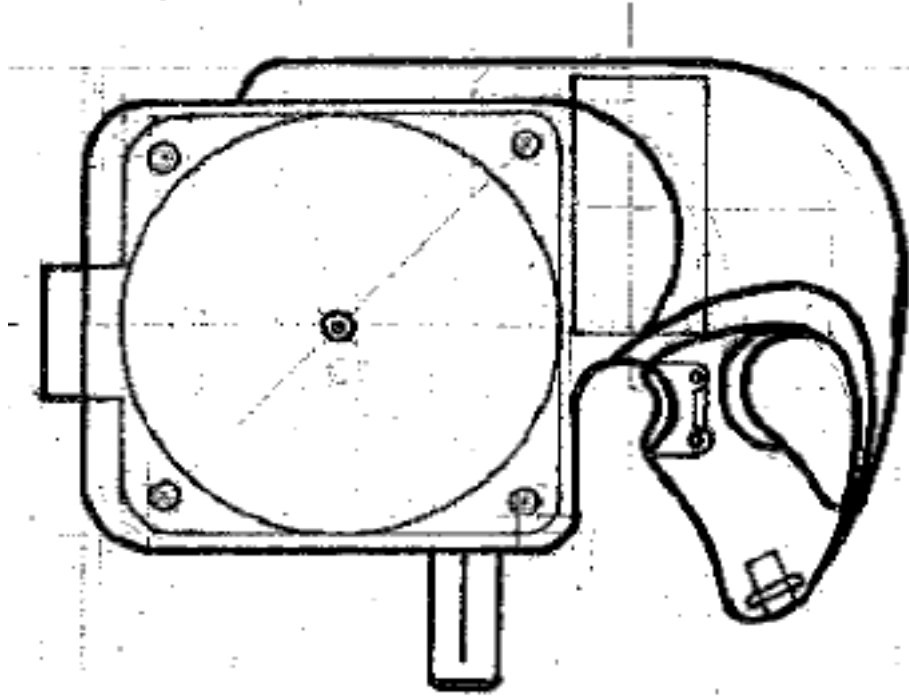
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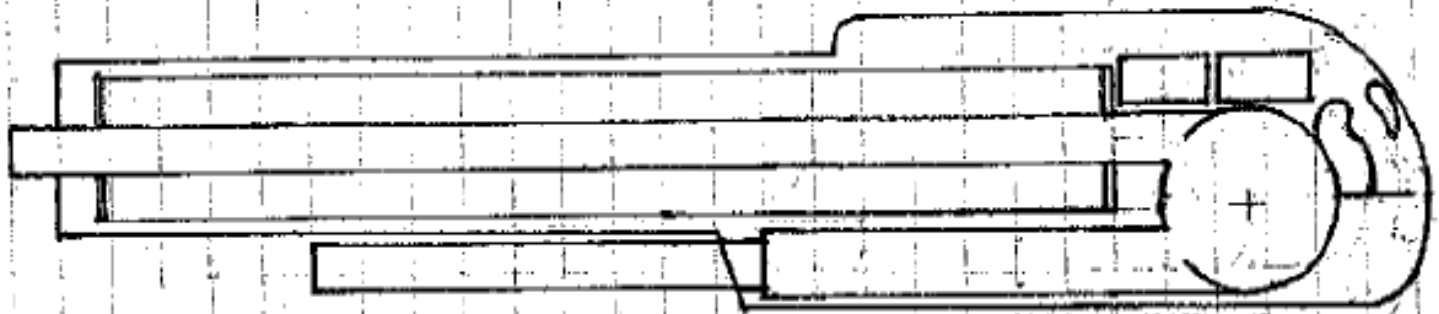
railgun designs



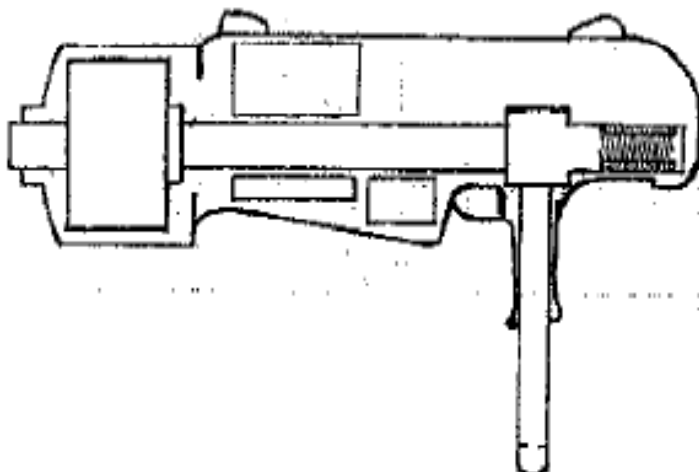
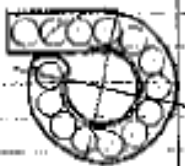
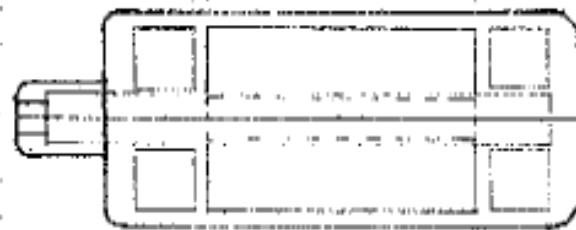
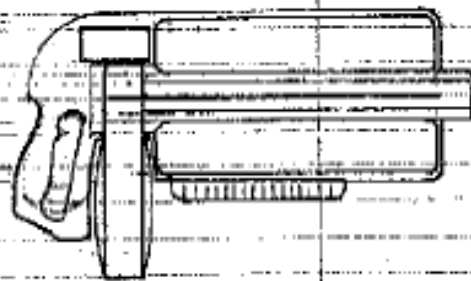
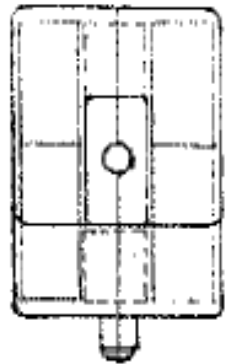
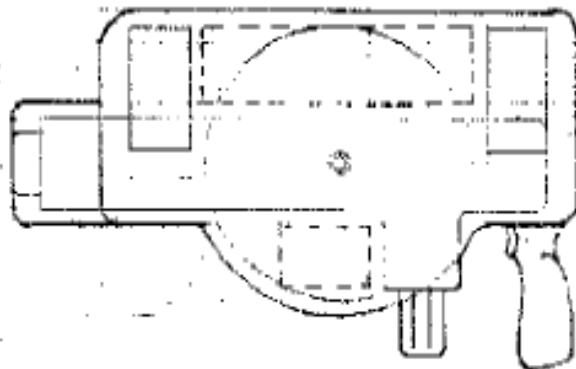
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45°

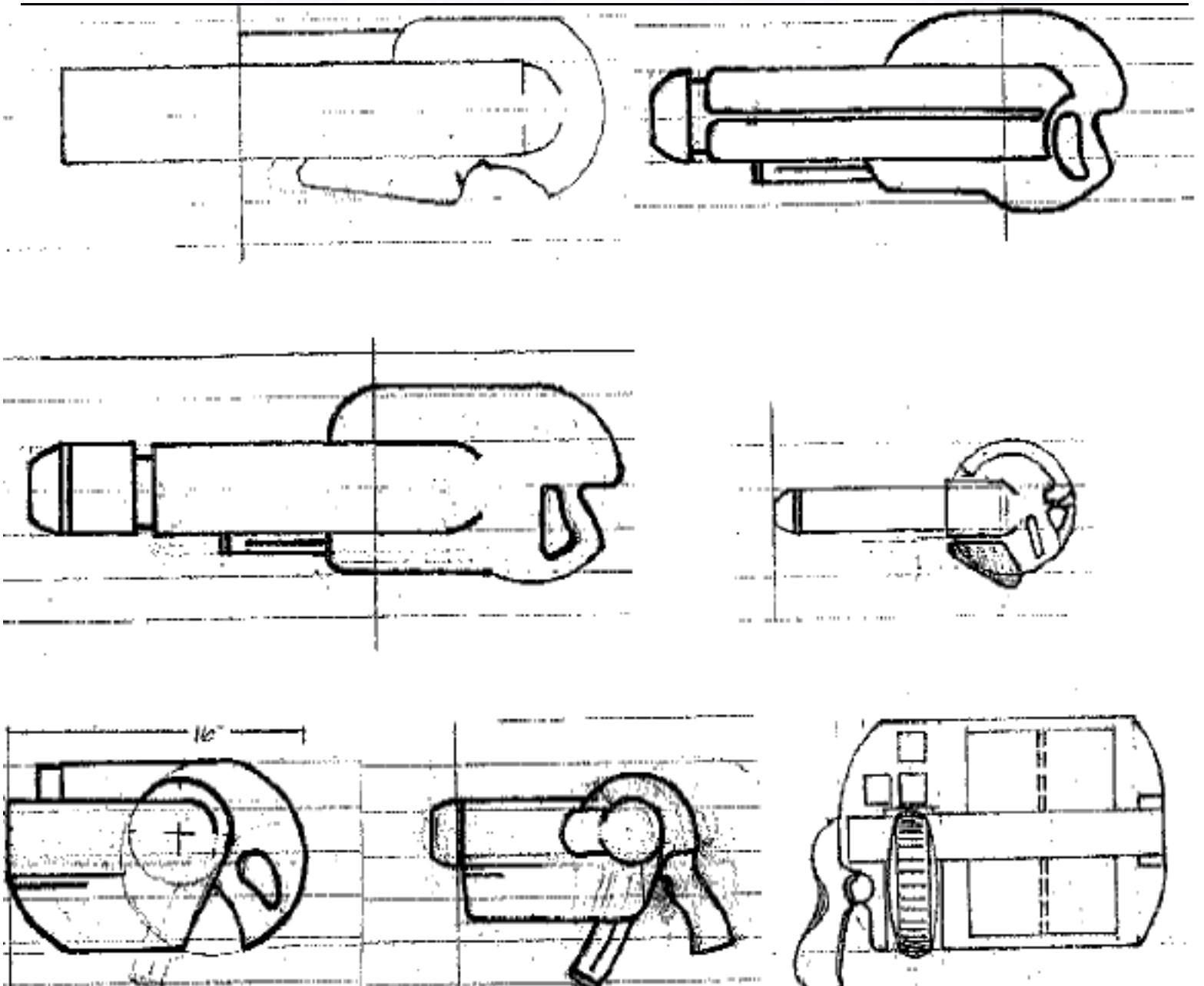




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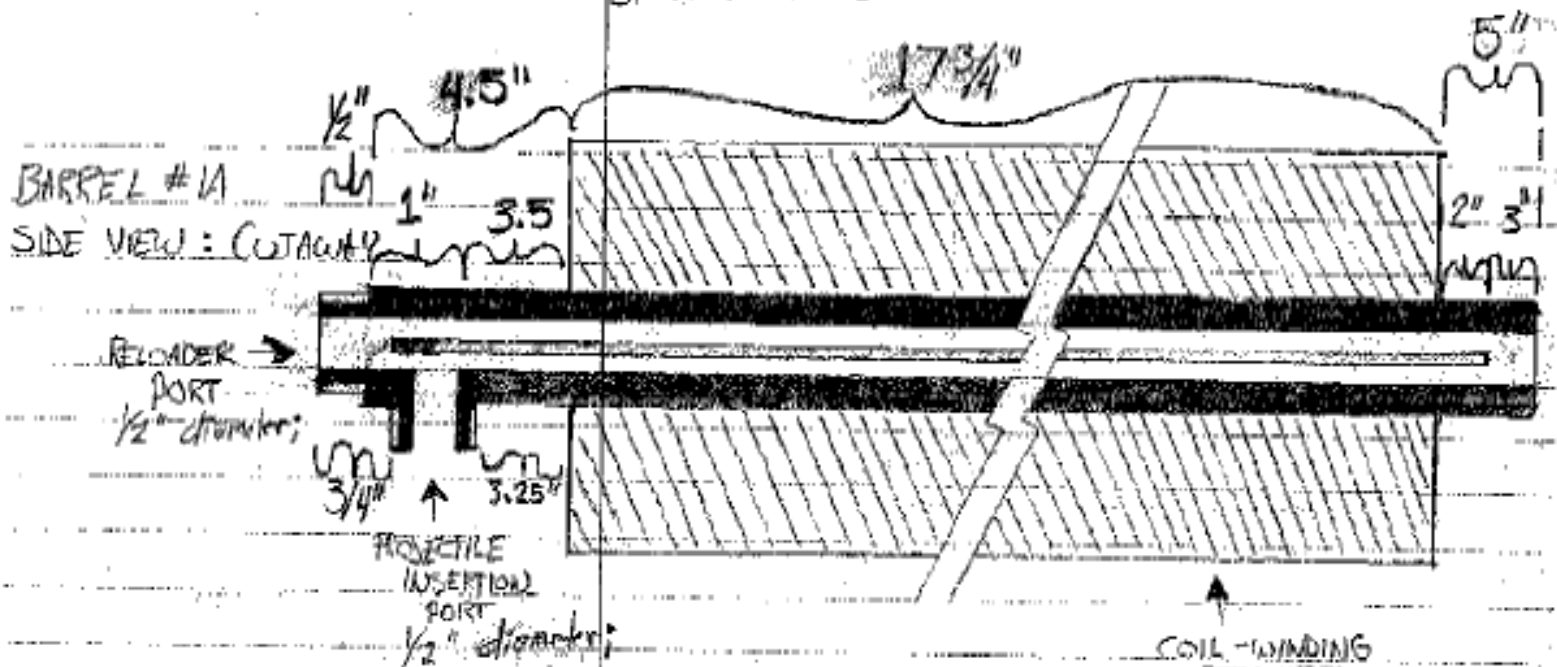


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LORENTZ-FORCE "RAILGUN" BARREL SCHEMATICS

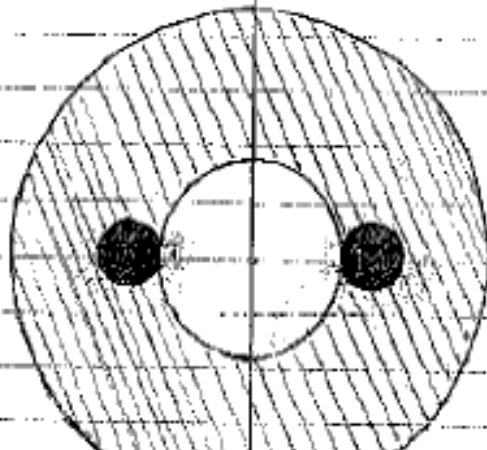


BARREL: OD: 1 1/4" total
ID: 1/2" total
OD w/RETAINERS: 4 1/4" tall
BARREL LENGTH: 29 3/4" total
LENGTH: 24" active
RETAINER LENGTH: 22"

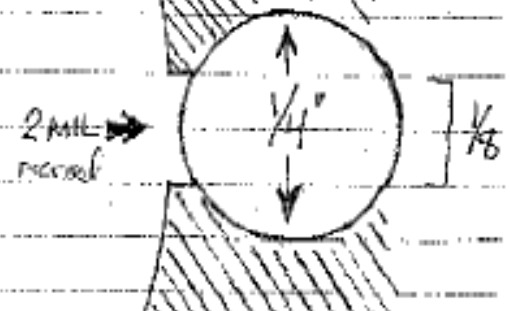
CASE MOUNTS:
1/4" tall; 1/2" depth;
23" Long
(not pictured)

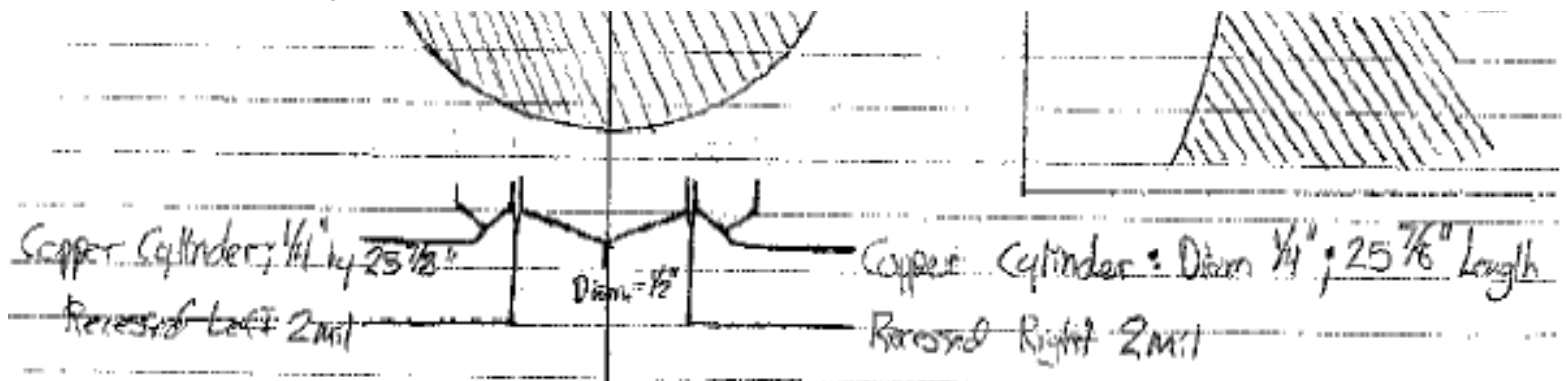
COIL-WINDING
RETAINERS
(Above & Below)
1/8" thick;
1.5" tall
23" Long

RAIL-SYSTEM
(center, shaded)
Length: 25.5" total; 24" active
Height: 1/8" surface; 1/4" recessed



RAIL-PLACEMENT CLOSEUP





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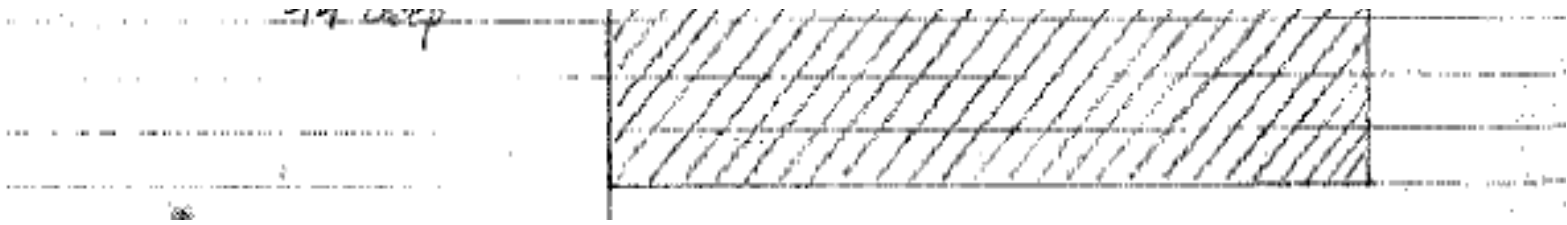
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The logo for railgun designs, featuring the words "railgun" and "designs" in a stylized, blocky font with a blue-to-white gradient and a slight shadow effect.

RIGHT: BARREL SECTION
SIDE VIEW; EXTERIOR

CASE MOUNT →

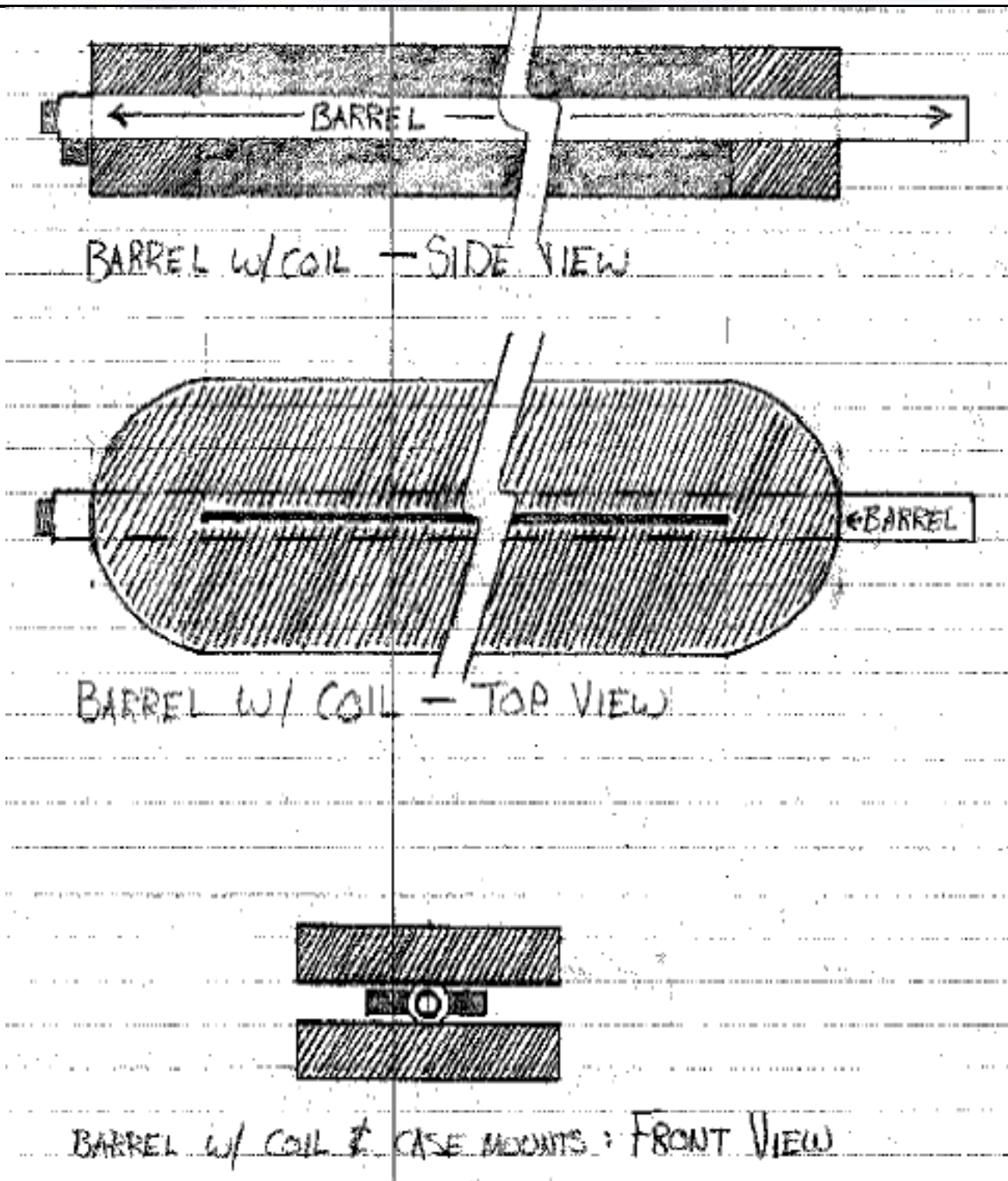
Circles indicate
bolt-mounting
holes; $\frac{1}{4}$ " diam.,
 $\frac{3}{4}$ " deep



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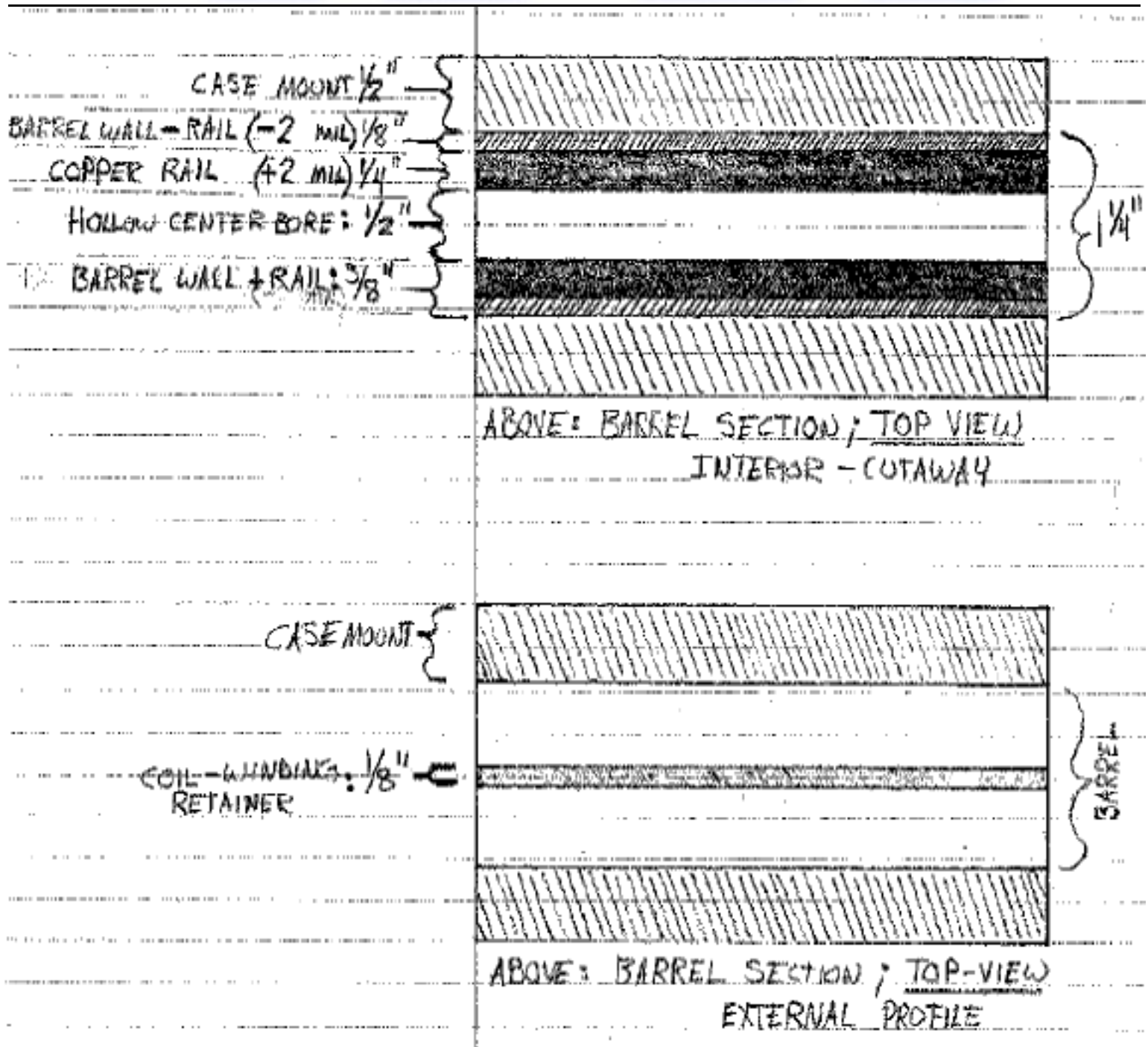
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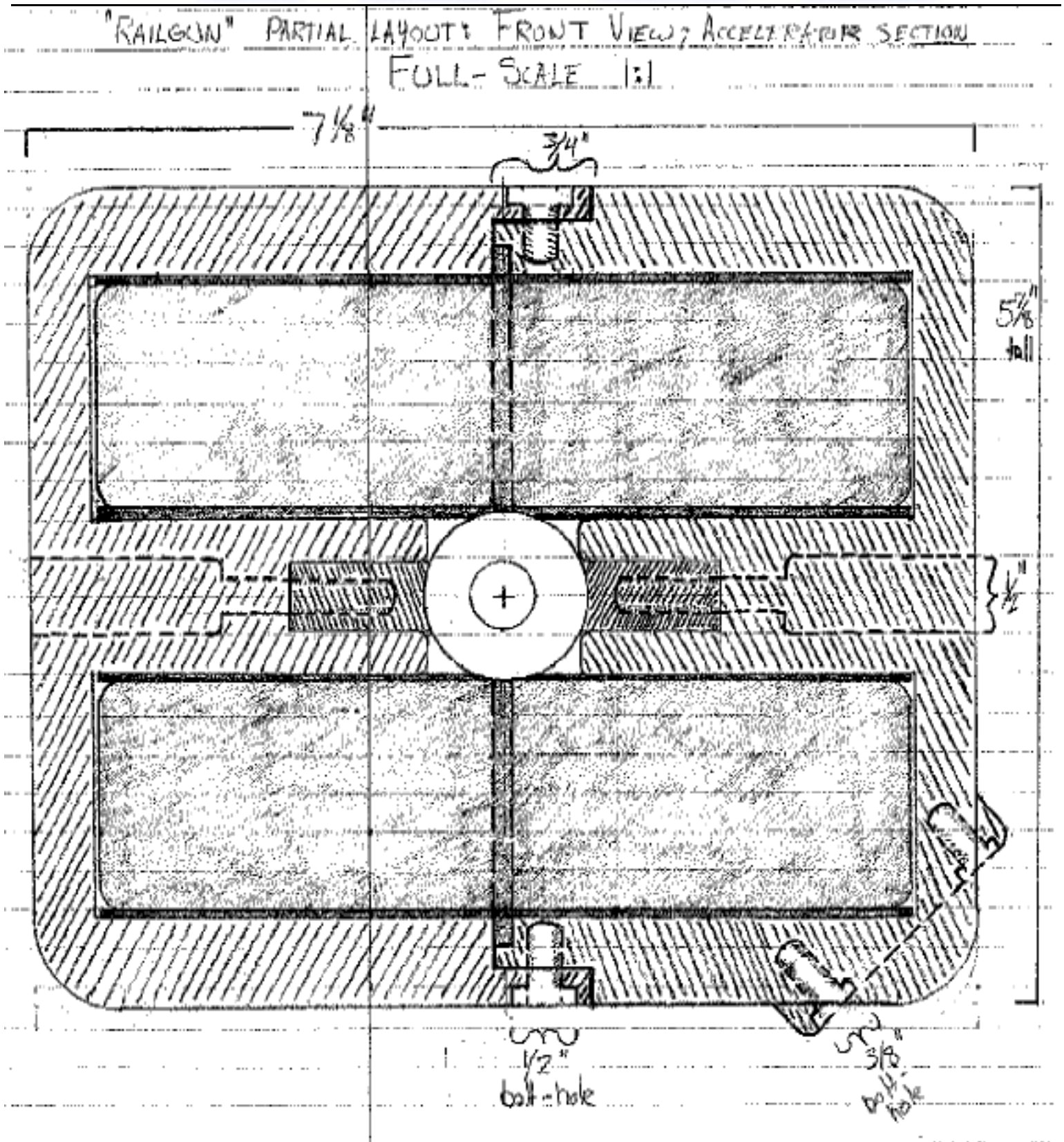
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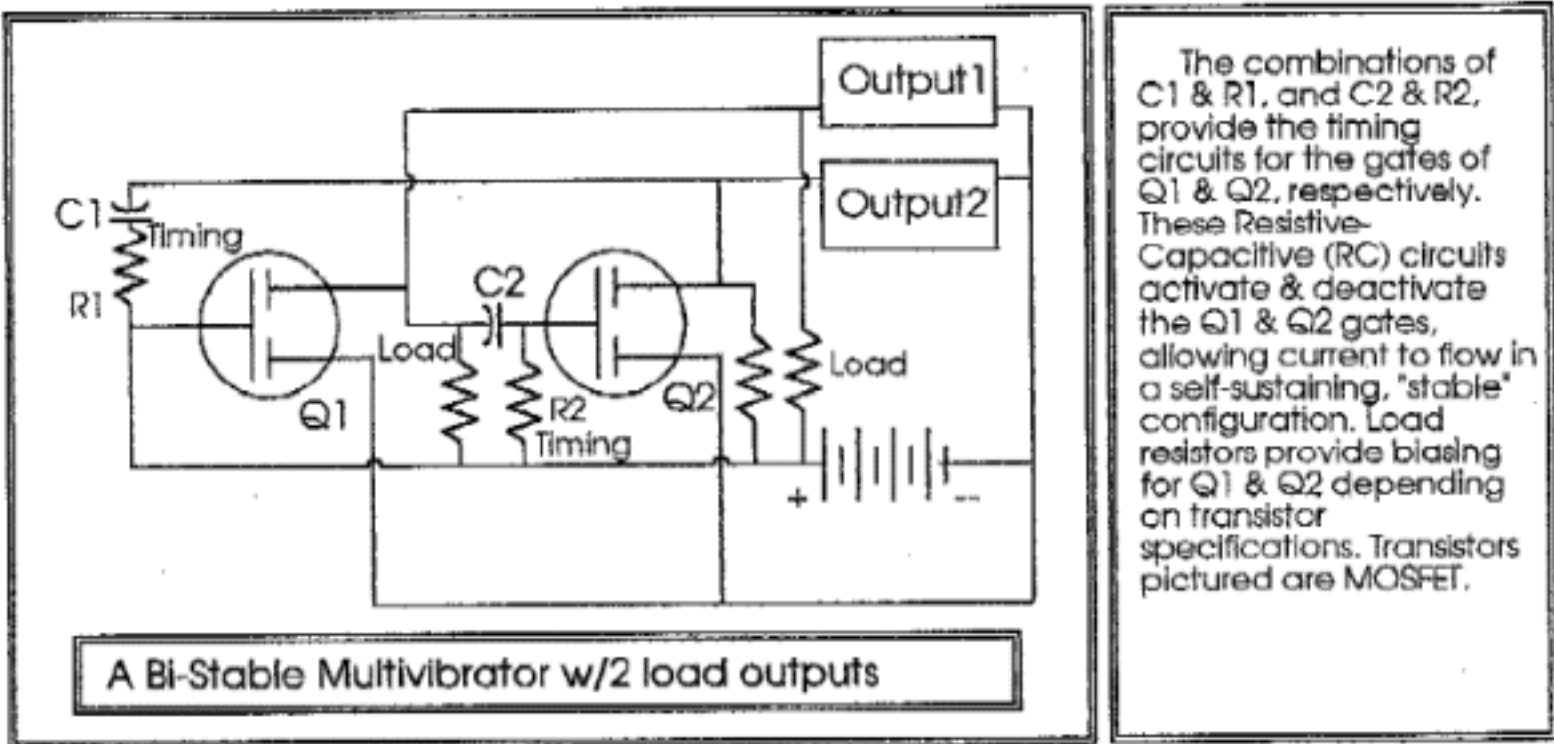
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The Multivibrator Circuit

The heart of the electronics system for the both the semi- and fully-automatic railgun and gauss rifle is an electronic timing circuit called a "multivibrator". This timing circuit consists basically of two transistors, usually labeled Q1 and Q2 (as in the example), that are linked together in a manner so that they activate and deactivate each other in turn.

There are several different forms of multivibrators, but there are a few defining qualities which serve to describe the primary features of this circuit. Foremost is the stability of the circuit. Multivibrators are either astable or multistable. The astable multivibrator is free running in nature--it does not stay in one state indefinitely, it keeps switching at a rate determined by the timing present in the circuit. The bistable, or multistable multivibrator does stay in one or more states until switched by another circuit or manually.

Specific Multivibrator Qualities

As described above, the multivibrator makes the perfect circuit for use in timing a semi- or fully-automatic electronically based weapon. The circuit is easily adaptable, easily adjustable, it can handle the enormous power needs demanded by the weapon's coil system, and it requires fewer components than other electronic timing circuits using similar power transistors.

The multivibrator, as pictured in the detail, has two "tapped" outputs--each output powers a timing circuit to the other transistors gate, as well as to its respective coil system--either the main coil or the reloader. Timing depends on the RC (resistive-capacitive) timing circuits connected to the gates of each transistor. These RC timing circuits determine the time that each transistor remains "on"--and can easily be adjusted by variable resistors, capacitors, or both.

Second is the number of transistors involved.

Although there are timing circuits comparable to the multivibrator that use only one switching component, a true multivibrator must have at least two transistors to function properly. A multivibrator is not required to have any certain number of transistors, other than the two initial transistors required of the circuit, and the addition of transistors may add a variety of effects.

Third is the number of states that the MV has. A multivibrator, for instance, with six transistors may have only two states--one or both of which may or may not be stable in nature. Another multivibrator circuit may have only three transistors, but each of those transistors has a discrete and separate state. Depending on the individual circuit, the multivibrator may be either partially or completely stable, and the various states may have different timing adjustments.

The voltage across the capacitors is equal in this case--for simplicity's sake only, however, the current limitations of the transistors may be met easily by adding parallel transistors in each "phase" of the multivibrator's operation.

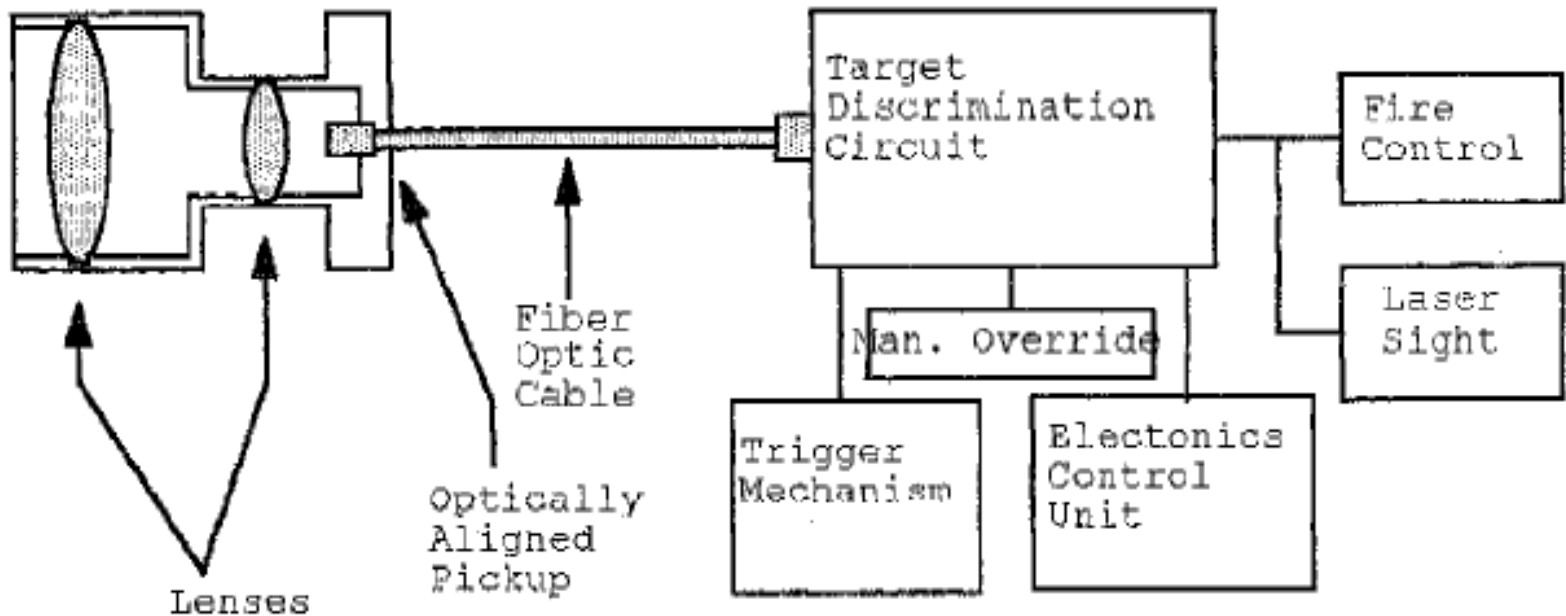
Moreover, several additional changes can be made to other aspects of this circuit. For instance, changing the velocity of the projectile from sonic to sub-sonic may be done by simply adding a resistance between the trigger-switch and the gates. Also, a selector between automatic and semi-automatic firing modes may be added near the sub-sonic switching mechanism.

This circuit, then, can be seen to be possibly the simplest, most convenient, and most durable timing circuit available for the railgun and gauss rifle, and it may be introduced into schematics very easily.

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● The Smartgun Feature

An additional feature may be added to either the railgun or gauss rifle that allows target discrimination. This smartgun feature utilizes a fiber-optically-aimed infrared body-heat detector link to the laser sight mechanism and/or the trigger. This feature would allow the trigger to be held in the fire position indefinitely, with the gun not firing until a human or animal came into aim--and the smartgun unit is active--either the laser sight activates immediately, or the weapon simply fires, or both happen simultaneously, depending on the user's selection.

This additional feature to the weapon would require an override link from an infrared body-heat detector to the fire-control circuit, as well as an additional manual fire override to allow the user quick access to weapon fire if need be.

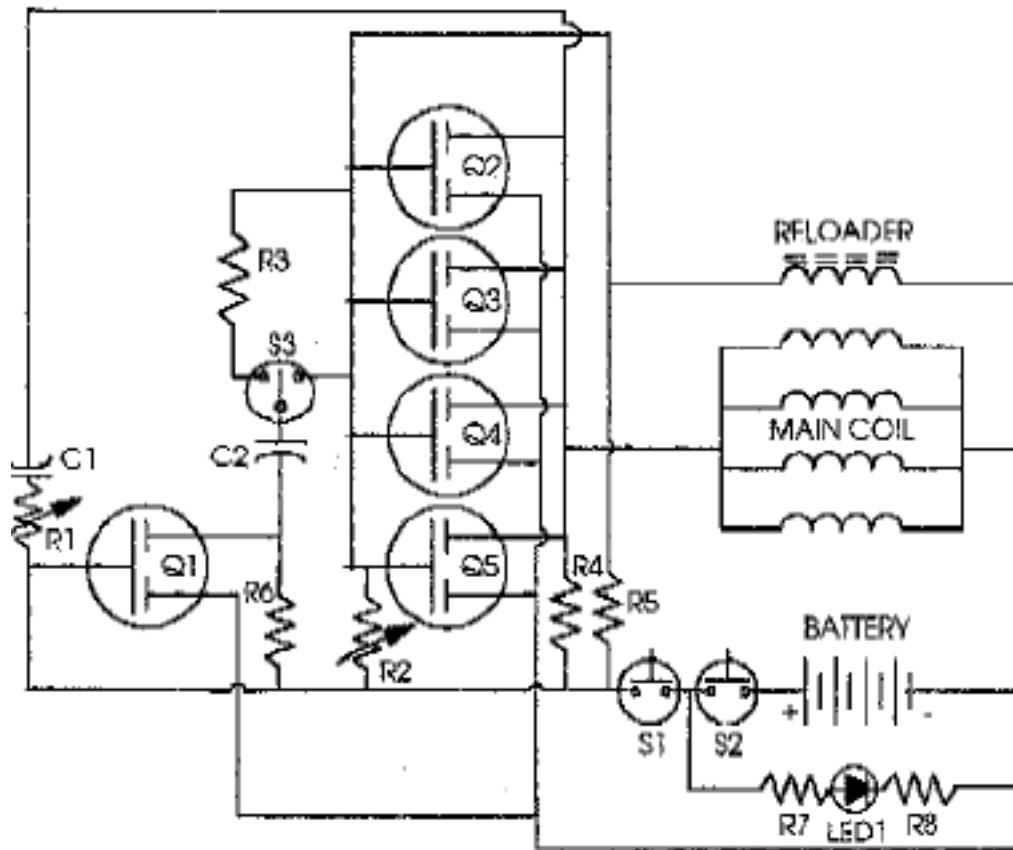
The actual body-heat detector would use a telescopically aligned sight-mechanism, linked by shielded fiber-optic cable to an optoelectronic assembly tuned to an adjustable frequency of low-band infrared radiation. When incoming radiation from the target activates the optoelectronic sensor, the discrimination circuit completes the fire control circuit and either the weapon fires or the laser sight activates.

The smartgun feature would have a base range of 100 feet, and hopefully a maximum range of about 300 feet--depending on the unit's sensitivity--and would be effective for short distances only. However, this feature would serve to conserve ammunition and increase targeting efficiency, especially at night when human visibility is greatly reduced.

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● Gauss Rifle Basic Electronics

The schematic above represents the electronics package for the extended prototype gauss rifle. It illustrates a fully automatic design with adjustable features, including adjustable rate of fire selectors, a supersonic/subsonic velocity selector, and a power status indicator.

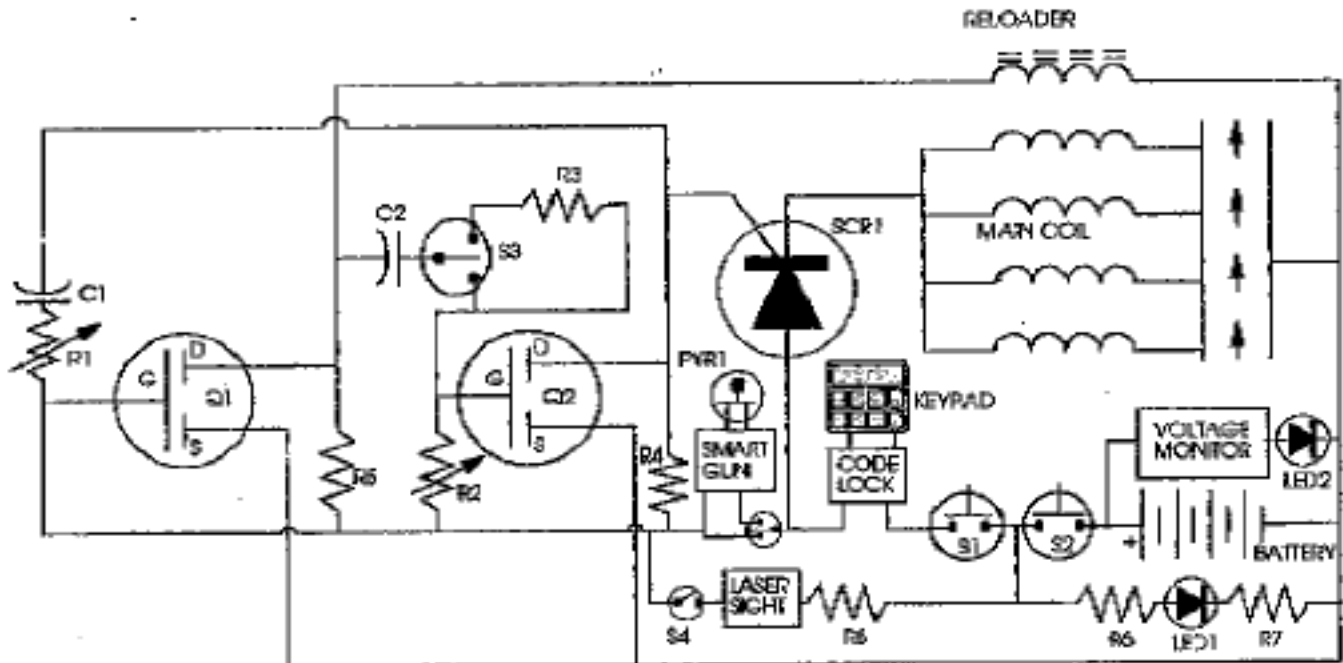
The rate of fire is controlled by variable resistors R1 and R2. These resistors control the gate voltage and current by their role in the Resistive-Capacitive (RC) circuit, and an increase in their resistance causes a decreased RC time-constant, hence, the firing becomes more rapid.

Switch S3 controls the supersonic/subsonic velocity selector by adding an increase in resistance into only the RC timing circuit of the main coil's power transistors. This also decreases the circuit's RC time-constant, which decreases the duration of the magnetic pulse. This shortened magnetic pulse in turn propels the projectile less, which translates into the projectile gaining less velocity as it accelerates out the barrel.

Light-Emitting Diode LED1 acts as a power indicator for the gauss-rifle--becoming lit only when the main power switch is in the closed position.

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Advanced Electronics

The pictured schematic illustrates the advanced features conceptualized for the production model railgun. Included are not only the previously mentioned timing adjustment resistors, but also a variety of other features, including an electronic code-lock, a trigger activated laser-sight, a voltage monitor to aid the power status display, and the smartgun feature.

The electronic code-lock (pictured with keypad) is inserted between the trigger and the automatic multivibrator. This is done in a manner to render the device useless if the lock is tampered with. The pictured lock would literally "kill" the power to the timing, reloading, and firing circuits--rendering the weapon useless if not first unlocked.

The trigger-activated laser sight is placed after the trigger, and is located so that it may be optionally used--turned on/off by switch S4. When "on", the laser sight would activate only during trigger activation--a feature which may be circumvented in final designs. The laser sight itself would consist of a visible-band laser diode, attached with mounting hardware to a semi-recessed position within the weapon's case.

The voltage monitor would remain dormant until the battery's potential fell below a predetermined limit. At this point, LED2 begins emitting light--signaling the user to charge the weapon's power source.

The smartgun unit (shown with infrared detector PYR1) would aid in targeting, and could be set by the user

to either ignore human targets or ignore all other targets. Depending on this setting, the IR detector would prevent the weapon from firing until the IR detector senses either heat or a lack of it. This feature would serve to conserve ammunition and aid in goal-oriented mission accomplishment, which may have specific restrictions for targeting.

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FEATURE COMPARISON

MAGNETIC IMPACT WEAPONS VS. CONVENTIONAL FIREARMS

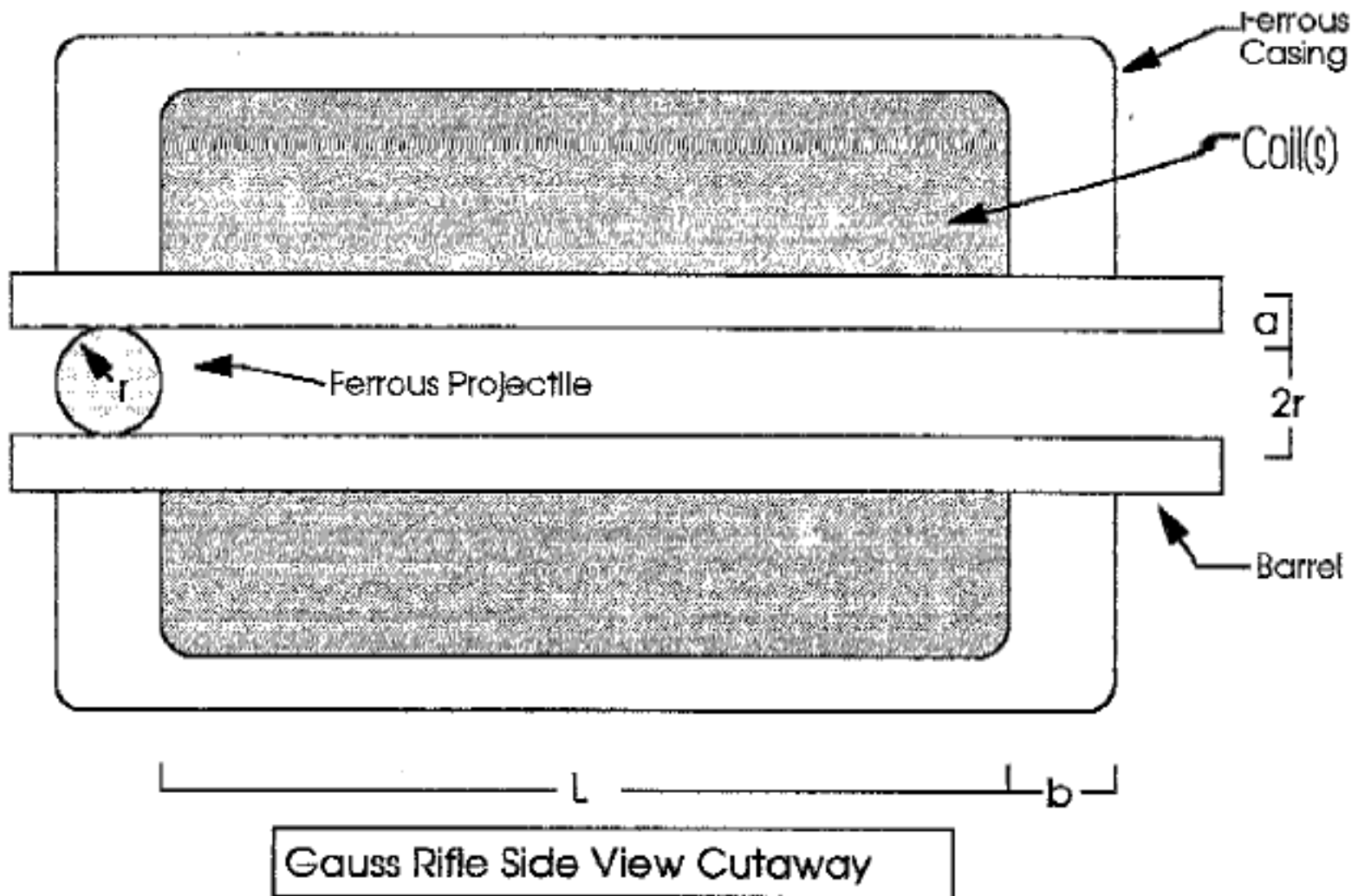
<u>FEATURE</u>	<u>MAGNETIC WEAPON</u>	<u>FIREARM</u>
1. Automatic	YES	NO
2. Adjustable Velocity	YES	NO
3. Adjustable Rate of Fire	YES	NO
4. Ammunition Count	YES	NO
5. Child Safety/ Anti-Theft Electronic Lock	YES	NO
6. Up to 100 caliber	YES	NO
7. Flash Suppression	YES	NO
8. Legally Silenced	YES	NO
9. Computerized Laser Sight	YES	NO
10. Malfunction Indicator	YES	NO

NOTE: Comparison involves features present on both magnetic and conventional impact weaponry legally available within the United States. Some features may be optional, depending on model and design specifics.

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● Gauss Rifle Physics Outline

The principles behind the operation of a gauss rifle rely on the mathematical expression for the force exerted on the plunger in a solenoid. This explanation accompanies several illustrated details which help clarify the dimensions and numerical values to be used.

$$F = A \cdot N \cdot I \cdot \left(\frac{\mu_0 \cdot N \cdot I}{2 \cdot (c)^2} \right) + \left(\frac{1}{CL} \right)$$

Where **F**=Force in Newtons (convert with railgun step#4); **A**=cross-sectional area of plunger in meters (akin to A in railgun step#2); **N**=number of turns in the coil (or use railgun step #1 multiple coil equation); **I**=current through coil(s); **μ_0** = $12.5663 \cdot 10^{-7}$; **c**= $ra/2b$; **C**=0.5 to 3, usually about 1; and **r**, **a**, **b**, **x**, and **L** are shown in the diagram.

Projectile Weights

The following are some weights for chrome-steel allow bearings, which make adequate projectiles for a prototype railgun or gauss rifle:

- 1. 0.5" (0.0127m) diam.....0.0017185 lbs. (0.00773325 kg.)**
- 2. 0.75" (0.01905m) diam.....0.05725 lbs. (0.0257625 kg.)**
- 3. 1.00" (0.0254m) diam.....0.1406 lbs. (0.06327 kg.)**

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● Railgun Physics Outline

Finding an approximate velocity for a projectile fired from a railgun requires a 4-step mathematical process. The 'process' focus is around Lorentz-Force--the physical law invoked with the railgun's operation.

Step #1: $H = (N \cdot I) / M$

Where **H**=magnetic field intensity in Ampere-Turns/Meter; **N**=number of turns in coil; **I**=current through the coil in amperes; **M**=distance between coil's poles in meters. This process determines the magnetic field-intensity for the coil system. For multiple, parallel sub-coils, the equation is changed as thus: **H** = $(N_s \cdot I_s \cdot S) / M$

Where **N_s**=number of turns per subcoil; **I_s**=current per subcoil in amperes; **S**=number of parallel subcoils; and **M** remains the overall distance between poles in meters.

Step #2: $B = (H \cdot \mu) / A$

Where **B**=the magnetic flux density in webers per square meter; **H**=the magnetic field intensity from step#1; **μ₀**=the permeability of free space ($12.56637 \cdot 10^{-7}$); and **A**=the area of the coil in square meters ($\pi \cdot R^2$). *This determines the magnetic flux density for the coil system.*

Step #3: $F = B \cdot L \cdot I$

Where **F**=force of the projectile in Newtons; **B**=magnetic flux density from step#2; **L**=diameter of projectile through which current will flow in meters; **I**=current through projectile in Amperes. *This is the force to be exerted on the projectile during firing.*

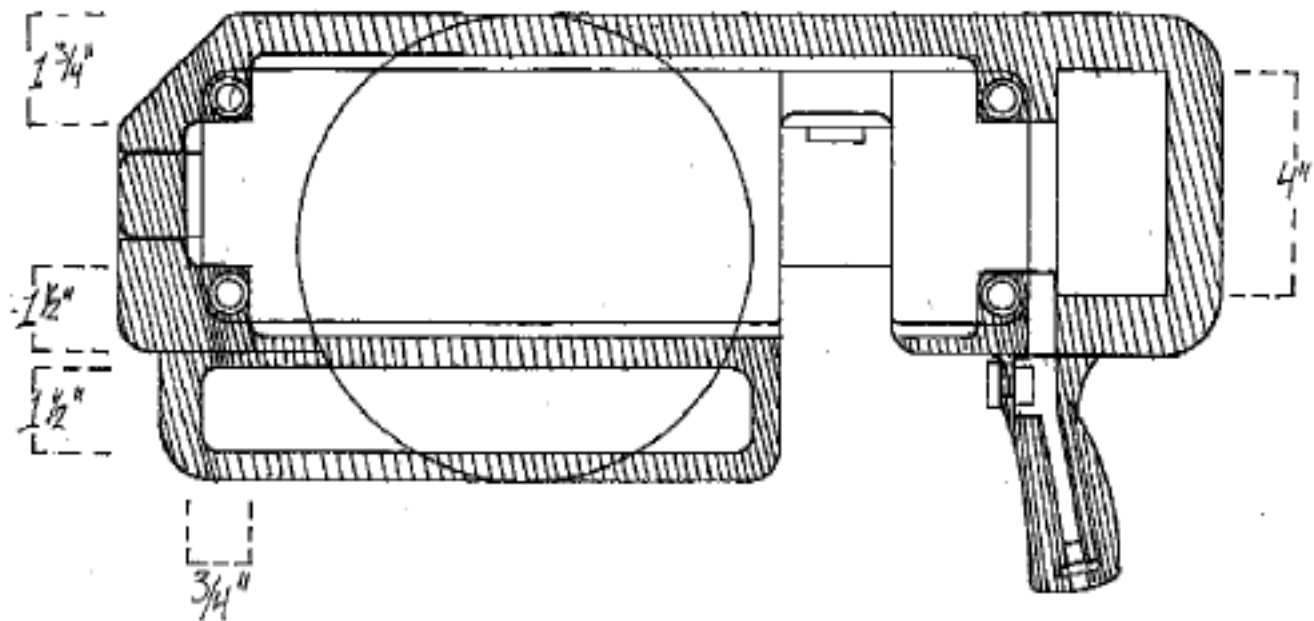
Step #4: $Spd = ((F \cdot T) / W) \cdot 3.33$

Where **Spd**=feet per second; **F**=force in Newtons from step#3; **T**=duration of acceleration in seconds (usually 1 to 5 microseconds); **W**=weight of the projectile in grams; **3.33** converts between meters/second and feet/second. This is a force conversion to translate force into speed, dependent on factors associated with the acceleration of the projectile in the railgun.

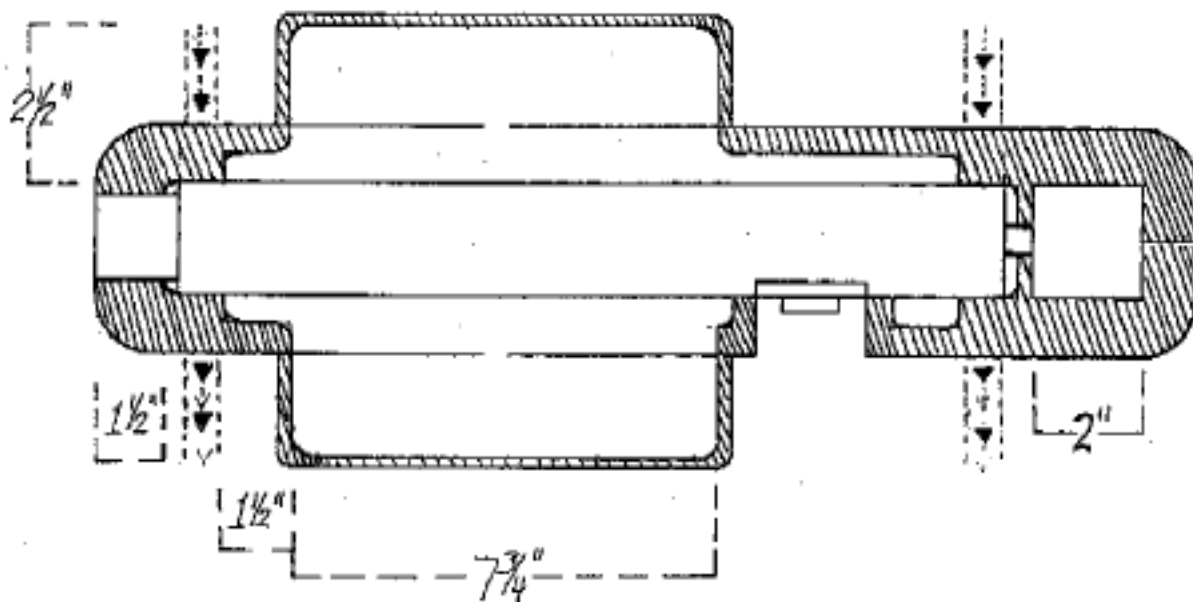
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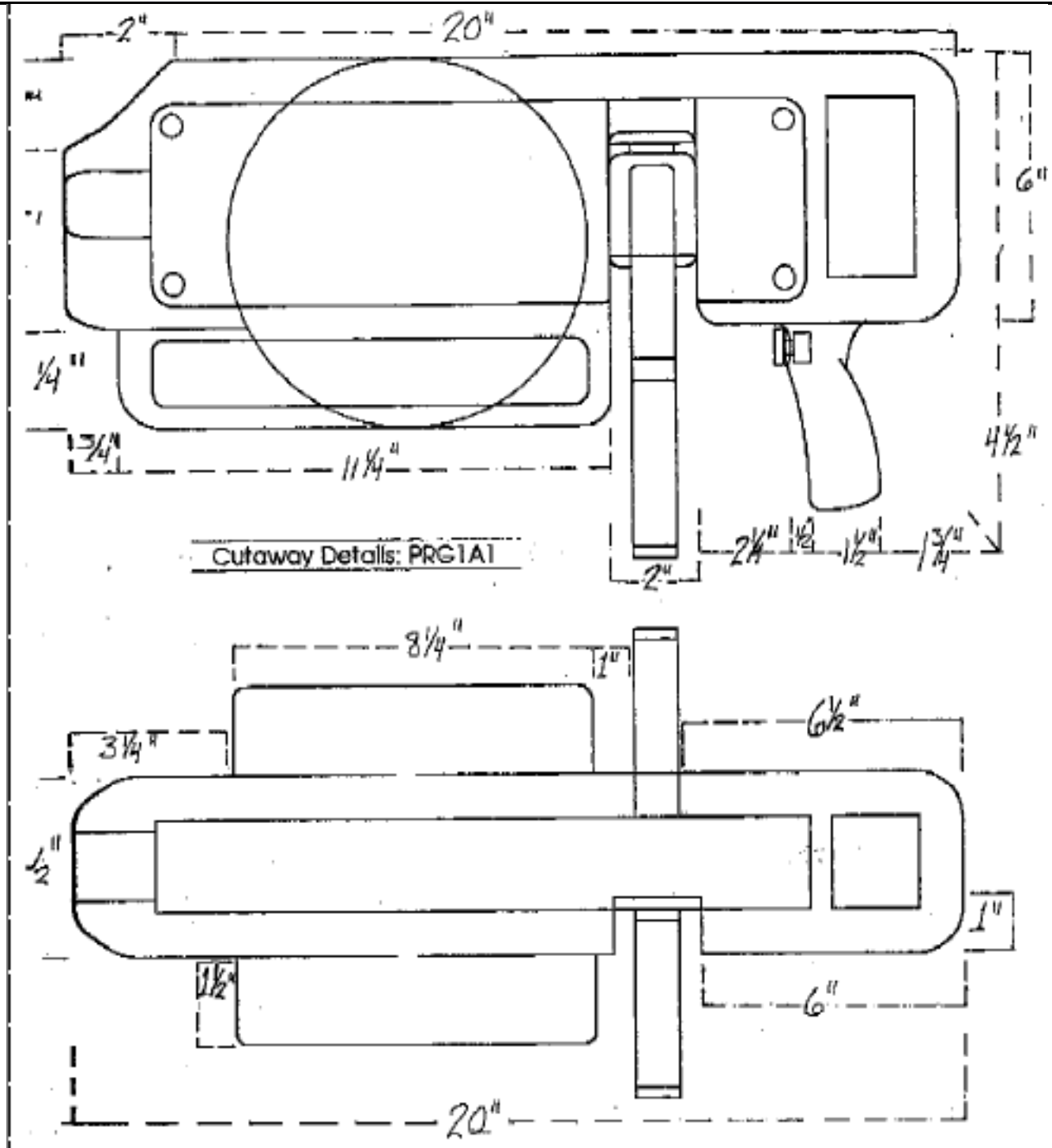
Case Interior Outline: PRG IAT



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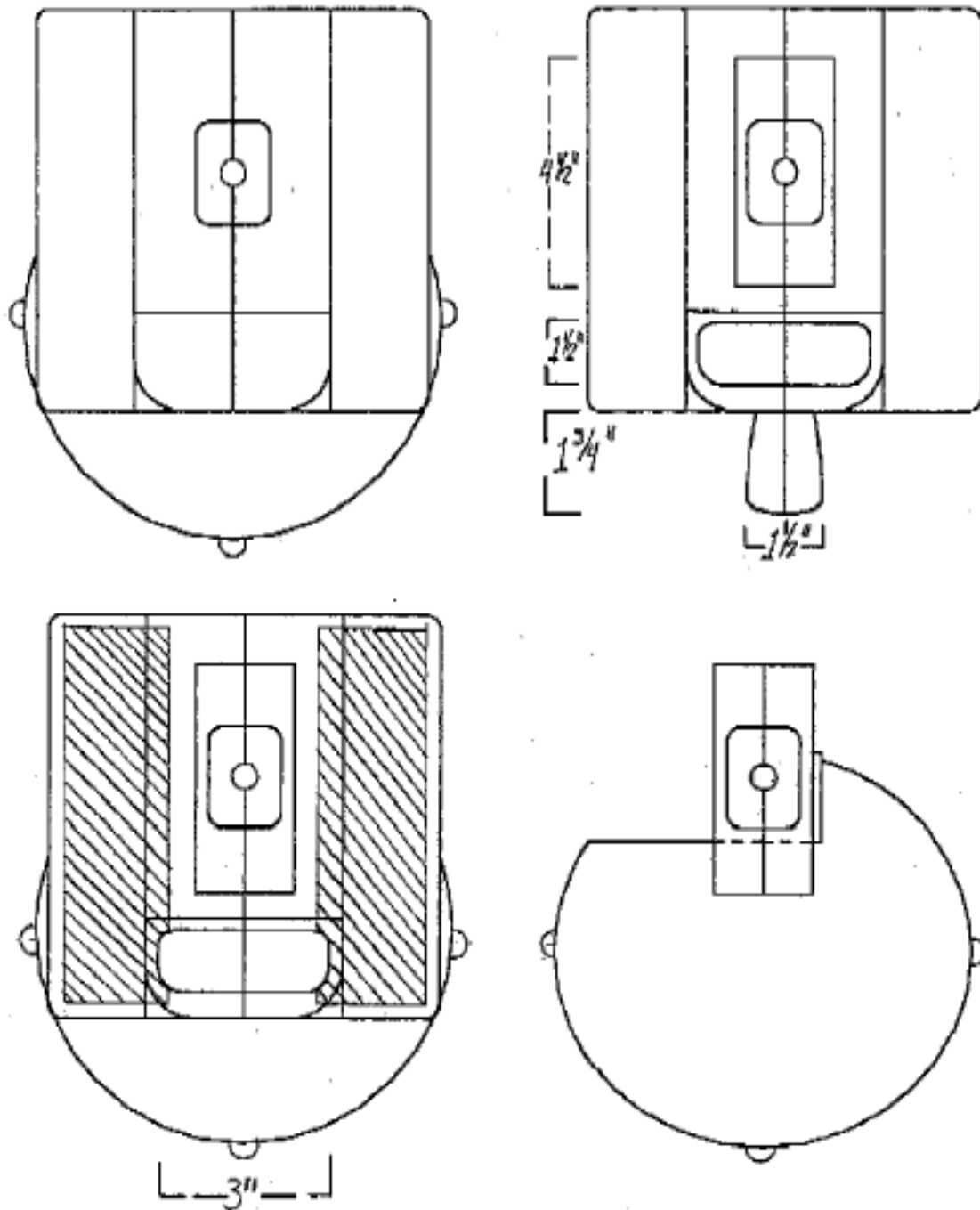
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Railgun Front View Illustrations

Top Left: External case view, with drum magazine attached.

Bottom Left: Internal outway view, detailing coil positioning, electronics & barrel placement, with magazine attached.

Top Right: External case view, with cutaways for electronics and barrel, without magazine—to show handgrip front layout.

Bottom Right: Barrel front view outway with magazine attached, to show positioning.

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